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Albi Alliaj

Rethinking Structural Design Values through Computational Culture and Contingency

IDAUP XXXVIII Cycle



Università
degli Studi
di Ferrara

DA

Dipartimento
Architettura
Ferrara



Rethinking Structural Design Values through Computational Culture and Contingency

Candidate: Albi Alliaj
POLIS Supervisor: Prof. Ilda Rusi
DA Supervisor: Prof. Michele Bottarelli

Cycle XXXVIII

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Rethinking Structural Design Values through Computational Culture and Contingency

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Candidate

Albi ALLIAJ

Supervisor POLIS

Prof. Ilda RUSI

(UniFe Matr. N. 188867)

(Polis Univ. Reg. N. PL581N110003)

Supervisor DA

Prof. Michele BOTTARELLI

External Expert

Prof. Alma AFEZOLLI

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Abstract

The advancement of computers has called the profession of structural design into question, because, if, previously, structural designers could boast of being masters of calculations, now computers are increasingly doing calculations. Consequently, this crisis brings the need for structural design to be re-evaluated once again to find other values in this profession, beyond calculations.

This thesis begins with a journey through the culture of construction to find values of structural design. Then, upon becoming a little more familiar with the values of the profession and structures, some assumptions such as structural optimization, structural efficiency, or even the perception of the structure as a conglomerate of discrete pieces of finite elements, are put into question.

During this journey, computational and social values are weighed against the contingency of structures, which represents the irregular and indeterminate side of the product of this profession. This feature of structures is not seen as an obstacle to be overcome, but rather as an opportunity to place structural design within activities that represent the full reality as lived, not the numerical world dictated by the traditional approach of structural design as an exact science.

The thesis studies the numerical world and, in particular, simulations and the problem-solving capacities of computers regarding structural design.

Lastly, the thesis suggests a method that can preserve structural values during design, as well as provide directions for future research regarding the potential of software in this area.

Keywords

Structural Design

Contingency

Cultural Norms

Computational Culture

Optimization

Sintesi in lingua italiana

L'avanzamento dei computer ha messo in discussione la professione di progettista strutturale, perché se in precedenza i progettisti strutturali potevano vantarsi di essere maestri del calcolo, ora i computer eseguono sempre più calcoli. Di conseguenza, questa crisi porta con sé la necessità di rivalutare la progettazione strutturale per trovare altri valori in questa professione, oltre al calcolo.

Questa tesi inizia con un viaggio attraverso la cultura dell'edilizia alla ricerca dei valori della progettazione strutturale. Successivamente, una volta acquisita una maggiore familiarità con i valori della professione e delle strutture, alcuni presupposti come l'ottimizzazione strutturale, l'efficienza strutturale o persino la percezione della struttura come un conglomerato di elementi finiti discreti vengono messi in discussione.

Durante questo viaggio, i valori computazionali e sociali vengono soppesati con la contingenza delle strutture, che rappresenta il lato irregolare e indeterminato del prodotto di questa professione. Questa caratteristica delle strutture non è vista come un ostacolo da superare, ma piuttosto come un'opportunità per collocare la progettazione strutturale all'interno di attività che rappresentino la realtà vissuta nella sua interezza, non il mondo numerico dettato dall'approccio tradizionale della progettazione strutturale come scienza esatta.

La tesi studia il mondo numerico e, in particolare, le simulazioni e le capacità di problem-solving dei computer in ambito di progettazione strutturale.

Infine, la tesi suggerisce un metodo in grado di preservare i valori strutturali durante la progettazione, oltre a fornire indicazioni per la ricerca futura sulle potenzialità del software in questo ambito.

Parole chiave:

Progettazione Strutturale

Contingenza

Norme Culturali

Cultura Computazionale

Ottimizzazione

Thesis title

Rethinking Structural Design Values through Computational Culture and Contingency

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Ph.D. Candidate: Albi Alliaj

POLIS Supervisor: Prof. Ilda Rusi

UNIFE Co-Supervisor: Prof. Michele Bottarelli

*Për mamin tim,
se pse e di që as barriera e gjuhës
nuk do ta ndalojë së lexuari këtë punim.*

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A.Alliaj, 2025

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1. INTRODUCTION

Chapter 1

1.1 The Role of the Structural Designer

With the advancement of computers, the profession of structural engineering has been put in difficulty because, if before engineers could proudly say that they were masters of calculations, now computers are increasingly doing calculations. Computers are the true masters of calculation. At the end of the day, to compute means to calculate. In recent decades, we have all seen how slide rules were transformed into calculators, then into software that analyzed a model, then into parametric programs that analyze hundreds of models simultaneously, and even the so-called AI, that have shown they are good at calculations by excelling in exams of various subjects in engineering programs. Consequently, the engineer no longer claims to be the master of calculations, and this crisis brings the need for structural design to be re-evaluated once again to find other values in this profession, beyond calculations.

A lot [of structural designers] are acting as human calculators and that's not engineering. If that is what people are doing, they will soon be replaced by computers, and that's a good thing. Because then they will be free to do what humans do best: complex problem solving; dealing with new phenomena; and being human. (Wise, 2016) [1]

Personally, I have also felt the storm of technological advancement that has engulfed us all. I have embraced technological advancements because I saw in them an extraordinary potential. I learned to code. I started by working for one and a half years to create a software that would automate the drawings of reinforced concrete beams for structural projects. Beyond the excessive time and effort it required to create—this was due to the complexity, as well as the lack of experience that I had as a coder that I lacked at the beginning—it has been a success and has been worth it. Now I can draw reinforced beams without getting tired at all, just by pressing buttons, and without worrying about making any human errors that usually occurred when drawing with CAD programs. Motivated by this success, I later created other similar software for the automatic drawing of columns, and the reinforcement quantity tables. I also designed scripts to automatically find the amount of reinforcement for slabs, as well as the cheapest slab typologies depending on the design case (regarding spans, loads, construction cost, etc.). All these programs have made my work easier. I still use them today, and I do not think I will ever go back to drawing these types of elements in AutoCAD. I am not alone. Many structural designers have had the same experience and have the same opinion. There is a new spirit that is felt in the air that makes us both curious and afraid for the future. If in most cases my scripts have shown that they work, and the implementation of new scripts to cover all the phases of designing a structural project is simply a matter of time and will, then doesn't this mean that we are putting an end to the problem of structural design? This means that, in most cases, we will not have to analyze the structures and with a click of a button, the structures will be designed without using logic or intuition. For those

of you who have always hoped that this day would come, I invite you to skip the pages and go see how these scripts work in Appendix at the end of this thesis. For the rest of you who have begun to doubt this computer-human relationship and are raising an eyebrow while reading this nonsense, then this PhD thesis is for you, and I invite you to read more.

First, there is a big difference between a structural engineer and a structural designer. Being an engineer means producing tools and then using them to solve problems. A designer does much more than that. Designing means creating. Structural design, beyond the professional difficulties dictated by the presence of gravity conditions, is a design process and as such, it is a creative process. To be specific, it deals with the creation of structural forms. It is very important to understand this from the beginning, since structural design has always been stigmatized as a purely technical process and has been given as a task to structural engineers. The effect that this detail alone has brought is very large. Engineers do not worry about values; they only worry about solving problems. In the case of designers, their main concern is in the philosophical aspect; to find values from the world around them and reflect those values in their projects. Structural design, being a process full of calculations, has been sidelined by architects and left exclusively to engineers to do, except of course in the sporadic cases where architects dare and undertake the design of the form of structures. Since these cases are rare, the creation of structural form has usually come from engineers, who, guided by the principles of the profession—at least those taught in university—refuse to think about the values of design, and seek only to solve problems related to gravity. Guided by technical skills and proud that they can “do things” instead of thinking, this profession has progressed through the centuries in this way. As long as real designers (architects, for example) were unable to intervene in form due to the high level of calculations required for these forms, structures were considered technical matters. Ironically, as we will see below, when you refuse to search for values, you embrace values imposed from outside.

Mario Salvadori, a professor of civil engineering, explains from his own experience why engineering students are so different from architecture students. He describes engineering students as not ambitious enough to become scientists: they are predisposed to accept the dictates of science and apply them to solve practical problems. He adds that they do not develop any critical thinking and are conservative when it comes to social and political issues. In contrast, he considers architecture students open-minded, adventurous, curious, critical, and independent. He thinks that architecture students are less interested in the practicalities of life and more interested in the complex problems of their society. They are also more diligent and eager to understand other people. [2]

Eduardo Torroja insists that structural challenges cannot be resolved by relying solely on structural engineering theory. Drafting a design and checking its strength is one task, but achieving the most effective solution and shaping the structure with the refinement of a true master is something altogether different. [3]

Walter Gropius also seeks something more when he emphasizes the importance of technological advancement and the creation of new methods for solving problems of form by engineers. He says: “Architecture starts where the engineering ends.” [4]

Ulrich Pfammatter posits another difference between the professions: “For an engineer, most design effort involves analysis. For an architect, design is the process of synthesis.” [2] In the clash between these two completely opposite approaches, structural-technical analysis prevails, as Felix Candela admits when he acknowledges that the design process often involves a difficult negotiation between architect and engineer. As he concedes, “science prevails, and the final design has generally lost the eventual charm and finesse of detail dreamed by the architect” [2]. Jorn Utzon must have had the same experience during the design of the Sydney Opera House when he had to completely reconfigure its structure due to the difficulties in the analytical methods of thin shells at that time. The truth is that the dreams of structural designers have collided with the realities determined by the laws of physics and by the computational skills of engineers in all different periods of time.

Collaboration between the technical and creative sides in structural design is essential because it requires a high level of technical and design skills, as well as other personal and communication skills. Engineers also have a place in the computer age. As Andrew Charleson acknowledges: “Engineers need to steer a path that is respectful of architects’ need to explore alternatives and realize their design aspirations, yet provide guidance on what is technically feasible and appropriate.” [2].

“To engineer is human” [5], admits Henry Petroski. Computers are fast, powerful, and will give you the right answers as long as you give them the right information and the right algorithms; and they will give you the wrong answers just as quickly if the information given is incorrect. All engineers are oracles in the sense that they should know more or less the answers before the computer gives them. [6] An engineer also has the difficult task of abstracting problems. As the saying goes, “All models are wrong; some, though, are more useful than others.” You cannot model all of reality inside a computer. It is impossible to include all the imperfections, tolerances, exact loads, and qualities of materials used in a structure. Fortunately, the objective of engineers is not to find out how a structure will stand, but to make sure that it will not collapse or misbehave. As a result, they have to abstract the loads that the structure may have during its life, making sure to get as close to reality as possible, plus consider extra loads because “you can never know”. As Peter Debney says, “Engineering is the art of getting the answer near enough, with failure not being an option.” [6]

Cecil Balmond suggests that “we have a choice now of two worlds.” [7] The first is the familiar, hierarchical one, still full of potential for invention and creativity in architecture and engineering. The second is more generic and nonlinear, requiring new approaches to

construction, the use of new materials, and ultimately fresh ways of conceiving architectural programs. This alternative world, he argues, will bring architects and engineers into closer collaboration, recalling the time when no distinction existed between the two and both were simply building designers. For Balmond, the future lies in an intense, immediate exploration between architecture and engineering, something he greatly anticipates. [7]

The demand for a better design

First, if I consider only structural performance, there is an increase demand for structural forms that solve performative problems. The environmental impact of structural design, for example, is becoming increasingly important. Not only do we need to deliver cost-effective projects for our clients, we also need to consider the cost to the rest of the world. The production of steel and concrete requires a lot of energy, which in many countries comes from power plants. The production of concrete also requires aggregates that are extracted from quarries, which also harm the environment. Moreover, cement production is a major contributor to CO₂ emissions. It is our duty as designers to address these issues during design and to be as efficient as possible. We can play a role in minimizing CO₂ emissions. Almost half of the volume of the structure actually supports its own weight, and despite this, we usually choose first a column or beam section and, as long as the checks are in order, we stick to that choice without disdaining that there may be other more efficient choices. Simply choosing the right section of the structural elements can bring a big difference to the environment; it can reduce carbon dioxide emissions, the extraction of aggregates from the ground, cement production, etc. It used to be said that 75% of the energy consumption in buildings comes from their energy performance during their life, but this is no longer true. The energy performance of buildings has already improved thanks to better insulation and the use of sustainable materials. Now it is quite the opposite, with almost 70% of the total energy consumption in construction coming from the production of structures. [6] That said, it is even more important in this moment to optimize our structures, not just to set some dimensions and take them for granted as long as the conditions of stability pass. Of course, we should not under-design, but over-designing has become a very widespread problem in structural design. According to Debney, “...structural engineers regularly over-design, with much of a structure working at about 50% utilization and most structural material is only at about 10% utilization.” [6]

Design is an unfamiliar concept in the engineering field. They say they design, but my experience in the teaching field has made me realize that engineers are not concerned at all with the synthesis of form. Instead, they are concerned with technical problems, hoping that the form will flow naturally from some previously used technique or from some condition in the design codes. Creativity, the one that is required to achieve a structural form in a genuine design, is as unfamiliar to engineers as the Bernoulli's equation is perhaps to architecture students (both are important for design, though). If we refer to design codes,

design is a process that is mainly concerned with the dimensioning of structural elements, determining the necessary reinforcement, and ensuring the strength, stability, and durability of the structure. These characteristics are actually of the detailed project, the one that is finally drawn up to go to the construction site, which I have tried to automate and, to a considerable extent, I have succeeded. The detailed project is generally a mechanical process, and there are very few possibilities for choice; as long as the inputs are known, you can derive the outputs from them. As such, it is a simple way to test students at universities. At the same time, it is the part of the design that has been more widely covered in recent years by computer programs. The other part of the design, often called the pre-design, is a much more complex process, where the creativity of the designer plays a role and is more similar to a real design. Debney describes this difference very well when he says: “While detailed design deals with ‘how much’, scheme design deals with ‘what’ and ‘where’.” [6]

As for the pre-design of structural forms, the value of the design remains ambiguous. Simplicity is usually seen as a good thing, as is efficiency. However, many successful structures are both complex and inefficient. Structural facades may also be required, but this may negatively affect the thermal performance of the building. Structural form may also be derived from a design manual, as it often happens: since the design code defines a set of structural elements—beams, columns, slabs of one-two typologies—the overall form emerges as a conglomerate of these elements. However, imagine how many other possibilities there are, perhaps much more efficient, that engineers do not take into account, following the latter approach. Not only that, but the truth is that there are always many more possibilities than those that can come to mind, no matter how open-minded you are. This means that the design of structural forms is always far from the best solution. This fact contradicts the claim of engineers that they have found the best possible solution when they determine the acceptable area of reinforcement from the bending moment formulas.

Instead of assigning a section and finding the reinforcement, designers should first ask themselves whether the sections are the cheapest. Will they easily find these sections in their city? Will they have an impact on the environment? On the other hand, what happens when they consider the impact of joints? There are cases when the structure is assembled faster if identical sections are chosen, but there are cases when this is not worth it because the structure can be greatly over-dimensioned. There are cases when choosing uniform sections can result in a cheaper structure, but can have a very bad impact on the environment.

The above questions remain, but there are other, more important questions. For example, it may be better to remove some elements altogether or move them elsewhere. Then, when considering unconventional elements such as trusses, the questions increase. You can remove some chords. You can completely change the typology of the truss. You can change its slope, which would greatly affect the incline required for water removal from the terrace.

The use of a different material can also be considered. So, to summarize, a change in form should be considered.

“What form should I make?”

A structural designer must answer this question in the design phase. The rest is more mechanical and therefore more amenable to computer automation.

To answer the above question, I need to define some values of what makes a good structure. The values may be efficiency, ease of construction, and beauty, but as mentioned earlier, even these values should not be taken for granted.

If we do not deal with the design of forms and leave it to the technical aspects to generate the form, we will soon be faced with a permanent conflict between the design of the structure and the design of the building in general. Often the structure turns out not to have the same values as the architectural forms, for example, and may seem to be forced within the building. No matter how much the designer in this case will insist that there is no other choice, no one can know how many possibilities a structure has without exploring them first.

Designing is a back-and-forth process with infinite possibilities. At school, we are not taught such a process. We were often asked to solve a problem that had a solution and, as long as we followed well-defined steps, we would achieve it. This is in fact the definition of an algorithm, which also explains why the computer has such an easy time giving the correct answer on scholar tests. At the end of the day, the computer has algorithms at its core. On the contrary, when designing, there is no clear path, and other groups of interest influence the solution. Sometimes you will have to meet the demands of these parties. Sometimes, you will have to negotiate. It may seem absurd to think of negotiating the form of structures since you are designing something that requires absolute stability, otherwise it will risk the lives of many people. However, do not forget that there is a very large, if not infinite, range of possibilities of shapes that meet the conditions of structural design. Also, remember that the structure is only one segment of the building, and there are other requirements that need to be met that come from other parties such as clients or building users.

To explore these possibilities, we can use the old trial-and-error technique, but this would be very time-consuming. The computer can help a lot with this problem, but how much work the computer will have and how much the designer will have in this process remains to be studied.

As you can already understand, the structural design I am talking about, that of the scheme project, which requires, among other things, creativity, is more of an architectural than an engineering issue. In this process, it does not matter whether structural engineers or architects themselves carry it out. The professional mark does not define the nature of the

problem. Dealing with problems of form in buildings is an architectural task in essence and, as such, requires more than just technical skills. It is time for structural design to stop being mired in the dogma of the technical professions and to be appreciated for what it is: design as a creative act.

Consequently, I will try to find structural design values in architectural design. “The purpose of architecture is to create space.” [8], says Hendrik Petrus Berlage. However, this does not simplify our problem, as the architectural profession has also gone through a series of stages that have reduced the concept of space to measurement regulations, giving priority to the technical aspects of design given in technical books such as Ernst Neufert’s book, *Architect’s Data to the Metric Handbook*. If we look at a simple house plan suggested by Neufert, we will see an abstraction of the living space in formal symbols. Jeremy Till explains this problem very well with three points. [8]

First, the furniture has a specific size according to the activity it is performing (eating, sleeping, watching television, and so on); then the spaces where the person moves are determined by the distances between the furniture and finally, the walls are determined by and follow the movement of the person. The whole process has an extremely simple logical flow, so much, so that if I were an architect, I would probably produce a script to automate the entire process of designing a house. But scratch under the surface, and many not-so-good characteristics emerge from these standards.

User of the house is treated as an abstraction. People are represented by lines, without considering their phenomenological and social presence at all. Their bodies are defined as if they were furniture, thinking only of their abilities to move and their stereotyped dimensions.

Second, it is the standardization of life processes, such as social behaviors or the configuration of the family, according to the size of the chairs and other furniture: The father is shown with a pair of slippers watching television while the mother washes the dishes. There is no room for deviation from the stereotype of a house, let alone the possibility of being represented if you step outside traditional gender norms or if you come from a religious community with distinct cultural norms. By default, it seems from the standard that, if you do not identify with that notion of family, you do not deserve to have a house at all.

Third, Jeremy Till does not fail to mention the reproductive nature of the standard: the default determination of the use of lead material for typical furniture forms, for example, which consequently determines the size of the furniture and the shape of the rooms needed to enable people to pass through these spaces.

The establishment of these assumptions heavily influences architectural projects, and it is assumed that the building will have the same characteristics on which they are designed.

Buildings are erected according to these assumptions and, as long as these conditions are met, they are considered successful. (I know this well because I have also “sinned” by suggesting this method to my students and by evaluating them on the values of this design standard in the subject of Architectural Technology.) However, this way of design is simply a closed loop that never questions the initial assumptions. It is a sign of a rationalist, positivist mentality that values standardization and rules at the expense of the diversity of life and life experience.

That said, perhaps the best option would be to ignore Neufert’s book as an extreme method, but this also means not taking into account the fact that it was a standard regulatory method for design in its time. Dropping those standards altogether means deeming that spirit of time as unworthy.

One may be beginning to notice, as one reads, how much political control has an impact on our professions, especially in matters of abstraction, ordering, and normalization. The good intentions of these documents in the name of advancing society, in matters of design, conceal a predisposition to normalization that, as William Connolly shows, is a symptom of all “liberal” democracies. He continues by saying: “The desire to establish the appearance of harmony in actual democracies, or the possibility of it in ideal democracies, suppresses the ambiguity of democracy itself.” [9] Consequently, even structural design does not escape this paradigm, having as its own purpose the denial and disregard of ambiguity that is beyond the control of structural designers. However, the specific treatment of design as above shows that this denial is not simply an insignificant feature that tends not to consider ambiguous cases, but is part of a more serious allegation that falls on structural designers and architects. By formulating space that according to them is only the tangible one, composed of materials, they make themselves servants of the demands of the market and give them an opportunity to distance themselves, to pretend that this happens involuntarily, from forces beyond their control, while their buildings represent clear political purposes.

Very few designers dare to begin the description of their project with the hidden collaborations in the design processes, when in fact their forms usually involve domination and indications of power. However, the above accusation, initially made by Jeremy Till [8], still stands, because the current values required for structural designing allow their product to be easily managed by market demands. By stripping them of their political and social content, space is easily reduced to those aspects of design that are easily manageable (beauty, technique, constructability) or to those characteristics of space that have to do with control (efficiency and construction time). In this way, designers of spaces—architects and structural designers—are complicit in enabling an alluring veil that hides and embellishes the heavy fist of urban expansion. This problem is exacerbated by the use of design codes, which, in addition to achieving safety, are concerned only with the requirements of the clients and not with the users of their buildings and those whose lives are impacted by these buildings.

Consequently, in order to fulfill their professional obligations, designers are content to respond to these requirements, which often have as their objective efficiency in the market and short-term profit.

Structural design is political. Period. I am not talking in terms of political parties, but political in the sense that it affects people's lives. Structural designers cannot continue to deny the social consequences of their actions by retreating to a "higher" corner—according to them—by abstracting structures as mere material spaces. Instead, we need to understand that the more we close ourselves off within the notion of structures as mere load-bearing machines, the more we allow the spirit of spatial control from outside to use us. Prioritizing physical spaces over livable social spaces brings about typical characteristics in structures: valueless, simplified, and therefore more manipulable. Spaces as measurable concepts bring about spaces that can be fragmented and controlled. Lefebvre reflected on this issue and acknowledged that social space is in fact a social product and, therefore, we cannot abstract the form or the world we live in as mere physical aspects that do not affect us. [10]

This sense of uncertainty that is offered to us by accepting the contrary—that structural design has interdependence with other fields—should not demotivate us. It is better, as a structural designer, to go out there and face these uncertainties. To be human again. To remember who you were before you took on the mantle of structural designer¹. To remember that you too inhabit this planet. To remember that you too use buildings and live in structures. Moreover, to remember that the users of these structures, including you, are much more than technicians or live loads; they are imperfect, diverse, non-explainable, and non-programmable entities.

¹ Props to King Mufasa.

1.2 Research Objectives

Traditional modern structural design—how ironic is this combination of words, which represents the contradictions of culture—was a game of synthesis between simple geometric shapes such as cuboids, spheres, cylinders and pyramids. The essential characteristic of contemporary structural design that challenges engineering is the pursuit of complex and continuous forms. Other forms can no longer be analyzed by decomposing and separating structural elements or by defining clear structural systems. This is important because it challenges structural engineering in respect of its basic elements and concepts. Modern forms of rationality in structural design are now being accused of inefficiency, while the rationality of older structural forms based on earlier traditions is being revived as a new design value. Such forms are Gothic cathedrals, which have acquired the status of efficient because of their good performance in load-bearing capacity. Patrik Schumacher states that this claim is based on calculations, which support the idea of the efficiency of these structures being closer to the ideal form of the path of forces, compared to the 90-degree forms suggested by the modernist spirit. However, I believe that the influence on the evolution of the form of structures has its basis in other social and cultural aspects. Yet, regardless of the reason for this change in design approach and the post-modern influence, we are spectators of the proliferation of new forms and new formalist approaches. The opportunity that technological advances have given us to produce new forms has brought at the same time greater demands and responsibilities from structural designers in a society that is becoming increasingly more complex.

One novel and promising method in structural design is the incorporation of optimization methods while using Finite Element Analysis (FEA), focusing on the integration of algorithms and heuristics as designing procedures for structural designers, to achieve holistic solutions. Unlike other computational methods, these tools seem to be all-rounded, versatile, and bypass the human capabilities for design. They ask from the structural designer to define their objectives before initiating the design process and then the designer just waits for the optimal product to emerge on the simulation. Then, the form is created during computer simulation through the process of topological optimization of the structural model.

There is a discourse connected with our zeitgeist that claims these methods can bring about not only stability but also other designing values. The assumption in this case is that, as long as the objectives are set, the structural form is automatically done. But structural design is a median, a form of communication. Its purpose should not be confused with the “How-s” of doing structural design. FEA and optimization methods are a “How”, more similar to the grammar of used languages than to communication as a concept. As such, these tools in themselves do not go after meaning, nor values. Just the presence of these tools does not justify a holistic structural design. Yet, it is a common belief between contemporary

structural designers that the tools advancement can make discrete elements inside the simulations to rearrange and create reality, but this should not be taken for granted.

The current premise in structural design suggests that the ontology of structural analysis has changed and now structural elements are no longer the elementary forms that are studied. Instead, the current contemporary approach considers as primary structural parts the “finite elements”, which are the mathematical units a FEA model is built upon. With FEA, it is possible to decompose the structure into small particles and calculate the forces, making it possible to decipher and analyze almost any kind of force path. On this assumption, discourses have also been raised in architecture that claim that by changing the ontology of structure due to computer advancement and exact science, it is possible to achieve architectural forms independent of the designer’s architectural composition, and to move towards generative computational design. “This is the era of structural fluidity.” [11], says Patrik Schumacher.

The same discourse also claims that the new ontology in structural design is bringing closer cooperation between developers, engineers and architects. They claim that this way of working has called into question their role—the structural designer is between the architect and the engineer, the computational designer is between the programmer and the architect or engineer, and so on. According to Schumacher, this approach marks the downfall of one of the main pillars of the modern project, which is the self-referentiality of communication systems, such as the economic, political, legal, scientific, artistic, etc. [11]

If topological structural models—compiled using optimization methods and FEA—can give meaning to the structural design of this era, their products need to embody the values of our zeitgeist. Therefore, I will start first with exploring those values and after finding those values, I will demonstrate if FEA and optimization tools alone can entirely fulfill the design obligations or somehow somewhere there must be a human touch to compose the structural form during the entire process, even after the setting of structural objectives. Afterwards, I will focus on the ontology of structural elements and understand whether “final elements” are sufficient to be considered as structural elements in our building culture.

Objectives:

- What are the values of structural design in our zeitgeist?
- Can computational objectives preserve structural design values?
- Did the ontological assumption that structures are made of typological elements change to the idea that structures are made of topological elements?

1.3 Notable Examples in Structural Design

In quest for structural design values, it is a tradition to make a quick search and see the values of some notable structural designs and their methodologies.

The Gatti Wool Factory (fig.1), erected in Rome in 1951, represents an example of Pier Luigi Nervi's design methods, which sought to minimize material use and achieved this by having material only along the paths of the lines of internal forces in the structure. The design's objective was to create an industrial building at the lowest possible cost by using the least possible amount of material while achieving good structural performance and spatial clarity.

To achieve this, Nervi based the geometry of the structure on isostatic lines, which represent the main trajectories of internal stresses. By placing the beams and roof chords along these lines, the structure distributes the loads efficiently. Therefore, he has have a form that is both economical in terms of material and optimal in terms of structure.

This project represents Nervi's general approach to design, which considers structures inseparable from the representation of architectural values. This geometry was not shaped solely for aesthetic reasons but derived directly from the mechanical behavior of the material under the action of loads. As such, the Gatti wool factory is often cited as an example of rationalist methods and the application of what would later be called performance-based design.



Figure 1 - Gatti Wool structure (adapted from Debney, 2021, p. 167)

The roof structure of the Olympic Stadium in Munich (fig.2), designed by Frei Otto in collaboration with architect Günter Behnisch and engineer Jörg Schlaich, is a typical example of structural design following the principles of form-finding. The main objective in creating the form was to minimize the surface area covered by the stadium, thus achieving a reduction for material usage while also gaining structural efficiency and a visual continuity with the surrounding landscape.

To achieve this, Frei Otto used form-finding techniques using physical experiments. In particular, he used soap film models, which create minimal surfaces naturally under the action of tension forces. These models enabled him to determine geometries that would achieve optimal force distribution and sufficient stability even when these forms were implemented on a larger scale, such as the case of the stadium roof.

The resulting roof is a lightweight tensile system composed of steel cables and transparent acrylic panels. Its geometry reflects the equilibrium shapes found in form-finding experiments, which enable the covering of large spaces using very little material and minimal thickness.

This design approach has established the Olympic Stadium as one of the visionary projects that inspired the creation of other computational and experimental methods in architecture and structural design.



Figure 2 - Olympic Stadium, Munich [12]

The design of the Sagrada Família church (fig.3), begun by Antoni Gaudí in the late 19th century, integrated principles of reducing bending moments in the structure. Gaudí's main objective with the structure was to create a form in which compressive forces dominated, thus minimizing or eliminating bending moments.

To create such a form, Gaudí used hanging model analysis, a physical form-finding method based on the principle of the inverted arch. By creating a model with tension-only elements, such as strings or cables, and letting them hang due to gravity, he obtained forms that worked only in tension. Based on Hooke's principles, if these forms were rotated 180 degrees, a form that worked in compression, with minimal bending moments, would be obtained.

This method allowed Gaudí to explore complex three-dimensional geometries that followed the natural flow of forces, particularly in the design of “mushroom” columns, vaults, and structures resembling tree branches. The result was an efficient structural system where loads were transferred through compressive force paths, reducing the need for massive structural elements.



Figure 3 - Sagrada Família, interior (author, 2017)

The Gherkin Tower (fig.4) is an office building in London completed in 2004, designed by Foster+Partners with the structural design led by Arup. One of the main objectives of the project was to minimize lateral loads, particularly wind loads, which are critical in the case of tall buildings due to their large effect on structural performance and the comfort of people inside. To achieve this, Arup implemented parametric modeling to explore geometric variants and optimize the aerodynamic shape of the building.

The smooth shape of the building and the curved geometry of the braces resulted from iterative processes with the goal of reducing the effect of wind vortex and wind loads.

The iterative processes were made possible by the use of parametric tools that allowed for step-by-step transformation and adaptation of the form to achieve the objectives based on performance feedback.

Then, in parallel, finite element analysis (FEA) was used to evaluate the structural response under the action of these loads, thus obtaining the most accurate stresses, deflections, and stability. The integration of FEA with parametric design enabled the structural design team to optimize the diagrid structural system, which is a steel exoskeleton composed of triangular modules that distributes vertical and lateral loads efficiently without the need for internal columns.

The mutual use of FEA and parametric tools in the case of the Gherkin tower illustrates a process guided by structural performance in which geometry, structure, and architecture are inseparable from each other.



Figure 4 - Gherkin Tower, photograph by Melisa Mali, 2023, used with permission

The redevelopment of Sydney's Ken Rosewall Stadium (fig.5), completed in 2020, included, among other things, covering the stadium with a 100-meter-wide canopy. The main objective of the roof design was to minimize its overall weight to enable its integration into the existing stadium structure without creating excessively large additional loads.

To achieve this, Arup used Finite Element Modeling (FEA) to simulate and analyze the structural behavior of different design variants under load. FEA enabled detailed assessment of material distribution, force paths, and deflections, allowing refinement of the roof geometry and structural layout.

The final solution consisted of a roof with cables working in tension and a membrane made of PTFE (polytetrafluoroethylene), which offers a very high strength-to-weight performance. The use of FEA enabled Arup to optimize the shape of the roof so that the cables worked in tension and structural stability was achieved with the least amount of material used, while making it possible to achieve architectural values and environmental requirements. The project is an example of how, using the computational method FEA, they could achieve design objectives, which in this case was to reduce the weight of the structure.



Figure 5 - Ken Rosewall Stadium [13]

At the warehouse Magazzini Generali (fig.6) in Chiasso, Robert Maillart designed a reinforced concrete truss system, the geometry of which was a direct product of the method of Graphic Statics. The objective was to minimize the material used by designing a structural form that follows the flow of internal forces, more specifically the path of compressive and tensile forces.

Unlike steel trusses, which have uniform thicknesses and repeating elements, Maillart's concrete truss allows for variable thicknesses and non-uniform elements, which can reflect the true distribution of internal forces. The generated form is as efficient in terms of material as it is expressive of its static function. The upper and lower chords are oriented in such a way as to reduce the principal stresses and eliminate an unnecessary mass of material. To achieve this objective, Maillart used graphic statics as a design method. By using a force diagram and creating a closed polygon that represented the optimal orientation of the truss's constituent elements, he was able to position the elements in such a way that they followed the path of the forces. This made it possible for the structure to have no excessive stresses and no material where it was not needed.

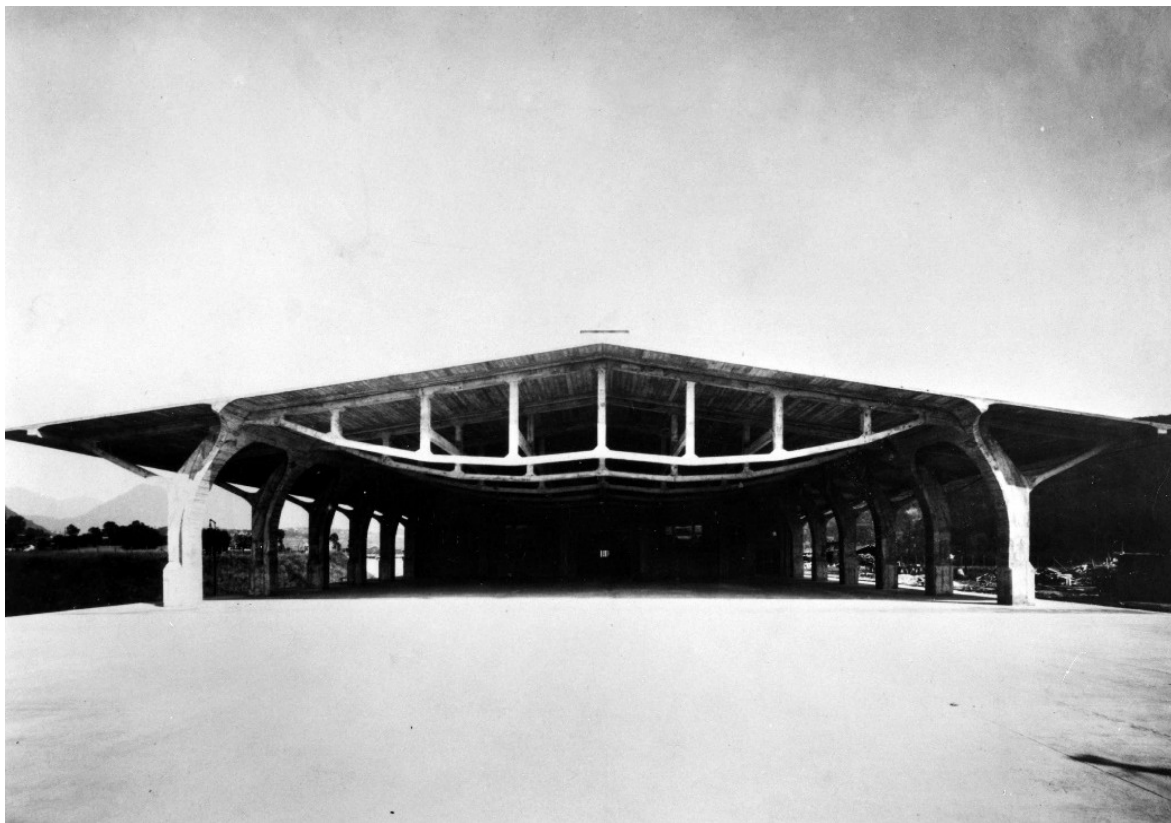


Figure 6 - Magazzini Generali [14]

The structure of the Oceanogràfic's restaurant in Valencia (fig.7), Spain, was completed in the early 2000s, and is based on the geometry of the shells generated by Félix Candela and represents his design objectives: to create structures with minimal bending moments. This was achieved with reinforced concrete shells with shapes such that they carry loads mainly through membrane action, that is, in compression and tension, not in bending.

Candela drew on geometric analysis, membrane theory, and physical form-finding experiments, particularly the study of hyperbolic paraboloid surfaces (hypars).

The hypar's double curvature enables the form to remain stable under load and distribute stresses efficiently, making this form ideal for concrete constructions with minimal reinforcement.



Figure 7 - Oceanogràfic (author, 2019)

When designing the Zarzuela Hippodrome in Madrid (fig.8), Torroja pursued the objective of achieving the minimum thickness of the cantilevered shell that would cover the spectators. To achieve this objective, he applied the principles of membrane theory, the same theory that Félix Candela used in the previous example. Membrane theory can analyze shells that, thanks to their shape, work only in compression or tension, without any stresses from bending moments.

The result of the shell structure was a series of curved cantilever modules with a thickness of only 65 mm at their top, which gradually increased towards the supports. The geometry of the shells was carefully generated to follow the natural path of the internal forces, allowing the structure to remain stable and efficient, despite its thinness.

Torroja's use of experimental models, as well as the application of membrane theory and an advanced understanding of material behavior by the designer, allowed him to provide a solution with high structural performance and material efficiency. The Zarzuela Hippodrome is an example of rational design where form flows from structural performance and is one of the classic examples in terms of the development of methods and designs for reinforced concrete shells.



Figure 8 - Zarzuela Hippodrome [15]

The Media-TIC Building in Barcelona (fig.9), completed in 2010 by Enric Ruiz-Geli and Cloud9, is an example that represents a shift in structural design to achieve environmental objectives, besides structural, specifically energy efficiency and climate responsiveness. It is a holistic approach, creating a form that satisfies both structural and environmental objectives.

A prominent feature of the building is the ETFE (ethylene tetrafluoroethylene) cladding system on the south-west facade. The structural frame of the facade supports these panels, which can create selective openings to dynamically regulate the solar gain inside the building. The geometry and arrangement of this structural facade were generated using parametric design and environmental simulation tools, thus linking structural elements to requirements for orientation and natural light.

The project also integrated structural logic with climate-responsive performance, including strategies for natural ventilation and daylight control during the day. Based on the project data, the building managed to save about 20%-40% energy compared to conventional buildings, and has been certified with the Green Building Award by the European Commission. [16]

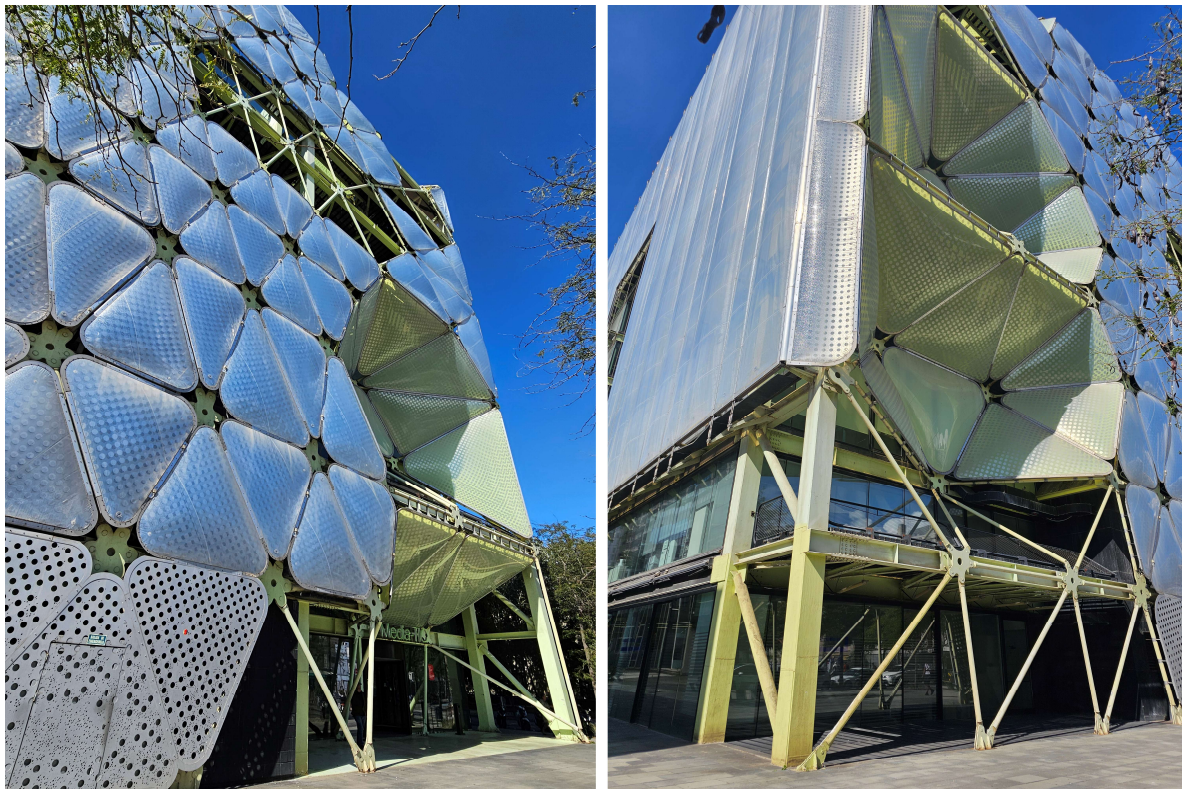


Figure 9 - Media-TIC Building (author, 2025)

One of the objectives of the structural project for the Sapienza University dormitories in Rome (fig.10), completed in 2022 by Proges Engineering, was to minimize formwork during construction. To achieve this, the company decided to opt for a system of shear walls and flat slabs without beams instead of the classic framed system made of beams and columns. The solution they decided to go with usually requires a greater amount of reinforcement and concrete, but, unlike previous examples, Proges Engineering and other companies that choose to use the beamless slab system have found other objectives to achieve in the design. By simplifying the formwork, the company predicts that the work on the construction of the dormitories will progress faster. The cost of the formwork will also be significantly reduced.

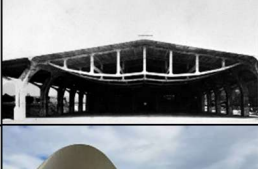
The methods followed for the structural design were a combination of FEA with manual calculations. The latter was especially necessary for calculating the punching shear reinforcement of the slabs. In the end, all the project drawings were made with CAD programs.



Figure 10 - Sapienza University Dormitories, structural design concept and render (Image courtesy of Proges Engineering, 2019)

Notice that structural design has always been about optimizing something. That “something” seems to be very ambiguous and often not reachable. Nevertheless, it is a tradition to solve problems of structural form by addressing the minimization or maximization of a certain objective.

Table 1 – List of notable structures

Structure	View	location, year, designer	optimization objective	design method
Gatti Wool Factory		Rome, Italy, 1953, PierLuigi Nervi	Minimal material quantity	The material follows isostatic lines
Olympic Stadium		Munich, Germany, 1972, Frei Otto	Minimal surface	Form-finding techniques
Sagrada Familia		Barcelona, Spain, Antoni Gaudí	Minimal bending moment	Hanging model analysis
The Gherkin		London, United Kingdom, 2003, Arup	Minimal lateral load	FEM and parametric modeling and analysis
Ken Rosewall Arena		Sydney, Australia, 1999, Arup	Minimal weight	FEM
Lagerhaus der Magazzini Generali		Chiasso, Switzerland, 1925, Robert Maillart	Minimal material quantity	Graphic Statics
L'oceanographic		Valencia, Spain, 1997, Félix Candela	Minimal bending moment	Membrane theory
Hipodromo de la Zarzuela		Madrid, Spain, 1930, Eduardo Torroja	Minimal thickness	Membrane theory
Media-TIC Building		Barcelona, Spain, Enric Ruiz-Geli + Cloud9	Minimize anual energy demand	Optimization methods
La Sapienza dormitory		Rome, Italy, 2022, Proges Engineering	Minimal formwork	FEM

It can also be seen from the table that design methods have greatly influenced the design of structures. For example, without the Finite Element method, the Ken Rosewall stadium roof would hardly have been possible, without the membrane theory Torroja and Candela would not have made their art, and without Graphic Statics Maillart would not have been able to create the forms that characterize his structures.

The structures above are all successful. They all achieved the conditions in solidity and deflections, but their forms are not related to each other. Above all, it is clear that the design objectives were different and independent of the notions of structural theory. If we were to talk only about achieving the conditions in solidity and deflections, even a tent could achieve them very easily, but does it meet the conditions to be considered a good structure for living? An arch with two support points can also meet the statics requirements. However, can it serve as a passage for wheeled vehicles? A metal box will most likely withstand the loads during its life, but try living inside an uninsulated metal box at an ambient temperature of 40 degrees. Hasn't it become clear by now that structural designers should look for design values elsewhere, outside their field, in order to design successful structures? This does not mean denying the value of structural science. Bearing capacity, allowable deflections, allowable drifts, conditions in overturning and sliding of foundations, etc. are not only important, but they are basic conditions without which a structure cannot be done. However, while these conditions must be met in every case, the design alternatives that achieve these conditions are infinite. Consequently, the designer must find values in the design and then translate them into objectives for achieving a form that meets these objectives. In the next chapter, I begin the search for finding these values.

2. CONTINGENCY IN STRUCTURAL DESIGN

Chapter 2

2.1 Structural Formalism and Why Things Don't Fall Down

I will begin the search with the Theory of Structures, which is the theory taught in universities to become a structural designer. If this theory is sufficient to guide designers in the application of their profession, then I do not need to look anywhere else. I will also see other unconditionally accepted values in the field of structural design that are more related to the ethics of the form of structures; forms that, for certain reasons, are accepted as better than others.

Theory of Structures: Classical Philosophy (based on J.E. Gordon's book, *Structures: Or Why Things Don't Fall Down*) [17]

A structure is defined as an assembly of materials that is supposed to support loads, and the study of structures is one of the traditional branches of science. Structures can—and do—fail if they are not properly designed, and this certainly has an impact, but, in the Theory of Structures, the stiffness and deflections before the structures fail are more important. The best structure is the one that, for a given amount of volume and material, has the smallest stresses.

The constituent elements of a structure are one, two, or three-dimensional. When we speak of linear or surface structures, we mean that one or two dimensions of that shape are smaller compared to the others. Many three-dimensional structures can be simplified in one or two dimensions. The designer generally tries to avoid large masses or blocks, in which all three dimensions are of more or less the same magnitude. Large volume dictates high costs. The pyramids of Egypt or the earthen masses of Babylon will remain in history as a great sacrifice dictated by an absolute rule by designated groups for the sake of an ideal that was not worth it, compared to the offerings that were made: it was worth much less than the human sacrifices that were made for it. If today's great dams are as gigantic in volume as the monuments of the past, it is only because engineers have not yet found for these applications another solution that is lighter and more efficient in terms of strength.

Naturally, the buildings that we see and admire are those that have survived. Despite their “mysteries”, skills and experience, the masters of the Middle Ages were certainly not always successful. A considerable number of their ambitious efforts were destroyed not long after they were built, and sometimes even during their construction. However, these disasters were seen as coming from Heaven to condemn the wicked and punish sinners, and not simply because of their incompetence and ignorance.

Perhaps because they were so fixated on the moral significance of their craft, the ancient builders, carpenters and shipwrights apparently never bothered to think, in a scientific sense, about why and how their structures were able to support loads.

Let's start with Newton, who said that action and reaction are equal and opposite. This means that every push must be balanced by an opposite and equal push. It does not matter how the push comes. It could be dead load, for example, which is in fact stationary weight of some kind. If I weigh 80 kg and stand on the floor, then the soles of my feet push down on the floor with a force of 80 kg. The floor pushes up on my feet with a force of 80 kg. If the floor is damaged and cannot produce a force of 80 kg, then I will fall through the floor. If by some miracle the floor were to produce a force greater than that, say 81 kg, then the result would be even more extraordinary because I would fly. If your feet push down on the floor, then the floor must push up on your feet. If a cathedral pushes down on its foundations, the foundations must push up on the cathedral.

In other words, a force cannot simply disappear. At all times and no matter what happens, every force must be balanced and reacted by another equal and opposite force at every point throughout the structure. This is true for any type of structure, no matter how small and simple or large and complicated.

If this condition is not met, and any of the forces is not in equilibrium or in balance with the others, then either the structure will break or things will start flying, like spaceships, and end up somewhere in outer space.

In the case of the cat's tail (fig.11), the reaction is made possible by the biological activity of the cat's muscles pushing in the opposite direction with the force coming from the action of the child's muscles. However, this example—between two living beings that actively pull each other with equal forces—is neither always present, nor the only manifestation of this phenomenon.

If the cat's tail were to be connected not to the cat, but to something inert, like a wall for example, then it would perform the pulling. It matters little whether the resistance to the pull exerted by the child would be provided by the cat or by a wall passively.

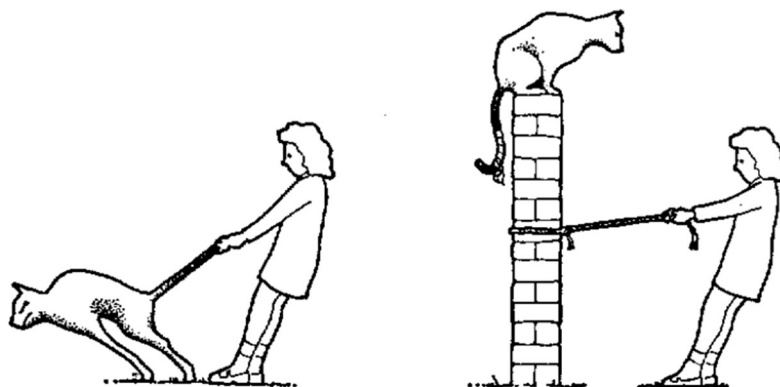


Figure 11 - Push-pull phenomena (adapted from Gordon, 1978, p. 36)

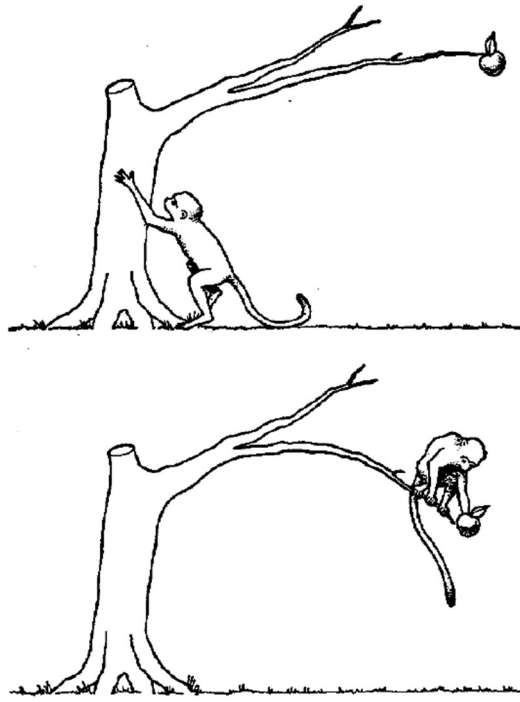


Figure 12 - Deflection phenomena (adapted from Gordon, 1978, p. 37)

Around 1676, Hooke realized that not only must solids resist weights or other mechanical loads by responding to them, but also that:

1. Every solid changes its shape under the action of loads;
2. It is precisely this change in shape that enables the solid to respond.

Hooke also made another important step in the theory of structures, which even today some people have difficulty perceiving. He realized that when a structure is deformed under the action of loads, the material of which the structure is composed also stretches or contracts, or rather its internal bonds. Later it was realized that these movements actually occur at the molecular level. So, when we deform a rod or spring, say we pull it, the atoms and molecules that make up the material move away from each other, or vice versa, they move closer together when the material is compressed (fig.13). As is now known, the chemical bonds that connect atoms to each other, and that make it possible to create a solid body, are quite strong and rigid. Consequently, when the entire material is pulled or compressed, millions of chemical bonds within it are necessarily pulled or compressed, and resist deformation. Thus, these bonds are the reason why the solid body produces the reaction forces.

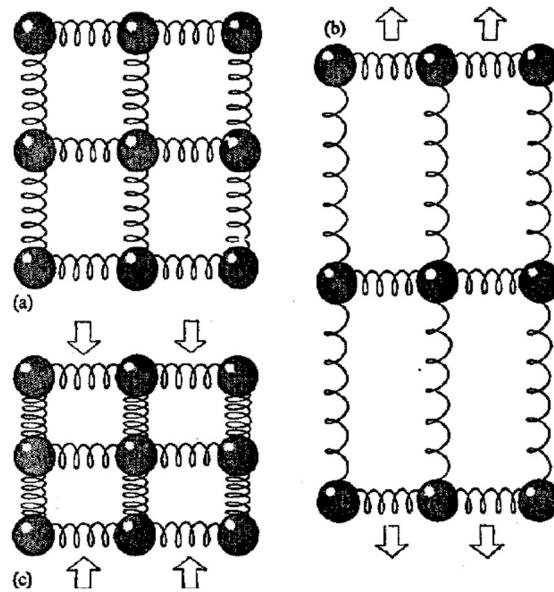


Figure 13 - Model of distortion of interatomic bonds under mechanical strain (adapted from Gordon, 1978, p. 39)

All these notions of stress and strain have in fact a human purpose, which is to enable us to design safe and effective structures and to better understand the phenomena that occur with structures. However, to achieve safety and efficiency, it is clearly desirable to predict how the various elements of the structure will distribute the forces between them in order to predict how thick or thin these elements will be. As mentioned earlier, structural designers usually want to know what deflections they will expect when the structure is loaded, because it can be just as bad for the structure to deform too much as it is to be too weak.

Regarding accuracy in calculations:

It is well established in all rational theories dealing with problems of strength and safety that the structural designer should be able to predict, with sufficient accuracy, the strength of a proposed structure before it is built, even when it is not known exactly how long its construction will take. While this may hold true to some extent for simple structures such as steel cables or wires and simple beams or columns, the truth is that for complex structures and structures where the loads are complex this assumption does not hold merit. Such structures are, for example, spacecraft and ships. Having an extraordinary experience gathered after centuries of construction, having so many computational methods for the analysis of structures and, despite the pride with which academics who explain the theory of structures want to express the opposite, the truth does not change. We still cannot analyze extremely complex structures with precision.

With bridges, the problem of calculating strength is somewhat easier than in the case of ships and spaceships, since the complexity of the loads is less variable. However, the number of failures in modern bridges or other complex structures is quite considerable.

One strategy for predicting the strength of a structure is to try to understand the weakest link in a load-bearing system. The more complicated the structure, the more difficult this becomes, and sometimes it is almost impossible. Fortunately, structural designers have often found it easier to determine the stiffness requirements more precisely and less complex than the strength requirements. In addition, if the structure is made stiff enough to meet the stiffness requirements, it can still be quite strong. Since deflections in a structure depend on its overall characteristics rather than the existence of any weak point, predictions for stiffness are much easier to make, and more reliable than predictions for strength.

Stiffness in structural theory is crucial because it dictates how the structure will resist deformations under the action of loads. Stiffness controls deflection and vibrations. Even if a structure has sufficient resistance to collapse (e.g., meets the conditions in the ultimate limit state), insufficient stiffness can lead to large deflections that make living in the dwelling uncomfortable and can lead to the destruction of other non-structural elements in the building.

Other important issues in structural theory:

First of all, in the selection of material, a structural designer must keep in mind that the materials used directly affect the durability of the structure. It is one of the primary objectives of structural design to produce structures with the greatest possible durability. There will come a time when the structure will be destroyed by external agents, as in the case of steel structures. Nevertheless, this cannot be ignored within the capabilities of the structural designer. For example, the selection of a high class of concrete has shown that the durability of the structure can increase considerably. Furthermore, we can select a timber material that cannot be damaged by microorganisms, or the use of various techniques for protecting steel from corrosion. [18]

In addition, an important aspect of design according to Gordon is the economic one. Furthermore, when the structural designer chooses what structure to make, he is faced with solutions that are easy or difficult to be built. The same applies to calculations. This does not depend at all on the client, nor on the contractor, and is a burden that falls on the designer. It is a matter of the designer's conscience, and he must be prepared to have the highest standard in his professional work. In general, the designer should seek to design structures that are as economically efficient as possible, but there are exceptions. When choosing the type of structure to use, other economic factors come into play that must be taken into account. According to him, a private and public work, or a luxury and industrial construction, cannot have the same approach and the same economic criteria. Even in the case between private and industrial buildings, there are sometimes personal or business reasons why the work will be more luxurious, thus justifying the expenditure of money on a more expensive structure which will increase the property value. A monumental structure may be required

for a bridge simply because it is located near a large city. Likewise, the effort for their design must be greater. The lifespan of wooden structures is not the same as that of steel, nor of concrete or stone. Nor will the dimensions of the structural elements be the same if the material changes. These factors are important when selecting a type of structure. It is not enough to simply claim that the structure should last as long as possible.

Peter Debney also affirms the values of structural design mentioned above:

“The principal goal of a structural engineer is to design structures that are: safe, functional, economic, sustainable and elegant.” [6] Even though “sustainability” has been added to the equation, Debney is not much different from Gordon and classical engineering in general. According to him, the main designer should focus on ensuring that his structure does not break (ultimate limit state) but is not too strong, because it becomes uneconomical. The structure should also be stiff enough not to deflect too much (serviceability limit state) but not too stiff to cause problems during an earthquake. To be sustainable and economical, their economic and environmental cost must be minimized. For example, according to Debney, this can be achieved by increasing the depth rather than the width of the beams, making them more efficient. However, he has understood the confusion that comes from the collision of design as a science with design as an act for people. He expresses this by contradicting the previous example. According to him, efficiency can also be achieved by doing the opposite, by reducing the depth of the beams and making them wider to maximize the height of the floor. Also according to him, the cost of construction can manifest itself as the money that the client will spend, or the time that the design company will spend designing that beam, but it can also go to the rest of the world: how much energy and carbon emissions this construction has consumed, as well as the production and transportation of materials. Then he mentions the elegance factor, which is perhaps the most difficult aspect to define. “Elegance”, he says, “is a value judgment.” [6] He concludes his idea by saying: “Note that many of these requirements are in opposition to each other, and an art of engineering is keeping them in balance.” [6]

Debney is not the only one who, while trying to explain the science of structural design, gets confused with its social values. Gordon, like him, fails to define whether structures should be efficient or not. Such confusions are frequent in the literature of structural theory, whenever certain aspects in the field of structures are mentioned, such as economic, social or aesthetic aspects, which belong more to human nature, that is, to social nature.

After these observations, we cannot help but become even more confused. If the structure should be as durable as possible, how much? If we must build as cheap as possible and in the meantime build expensive structures for high-class buildings, where do we draw the line? It is clear that these indicators are not measurable, even less so within the jurisdiction of the structural design profession. These indicators are clearly social ones. But structural design deals with structures, scientific studies, not with social problems, right?

Regarding the connection between structure and form, classical theories suppose that structure “simply gets in the way”. This condition is fundamentally accepted even from contemporary structural designers, like Cecil Balmond, who, regarding this case, says:

To ask a mass to levitate is not a new question; there is always an architectural demand for a lightness of being, tabula rasa visions with nothing to account for gravity. Structure in these situations simply gets in the way, becoming an enemy of promise. But gravity is a tyrant. Its pull cannot be avoided, and the usual response for supporting a load in the air is to configure legs to hold the weight up from below. There is a directness of purpose to this configuration but there is also a complacency to look for nothing else. (Balmond, 2002) [19]

The evaluation of structural forms as indicators of their performance under loads has been accepted in many cases as a value by architects and structural designers, including Louis Kahn, who famously stated, “The brick wants to become an arch”. This connection between statics and form is especially strong in the case of design in seismic regions. Nothing is more inimical to a structural designer than a complex form to resist seismic loads. As Andrew Charleson explains, earthquakes dictate that buildings not only resist large lateral forces, but also that they move in a controlled and predictable manner. [20] He continues the thought by saying that the form of the building is not a trivial choice but, especially in seismic regions, is one of the most important factors that determines whether the structure will survive an earthquake or not. [20] His concept of structural formalism rests on the premise that architectural and structural form must adapt to the conditions dictated by the earthquake. Such conditions are regularity in plan and height, symmetry of form and a small distance between the center of mass and the center of gravity for each structure, clear and uninterrupted continuity of the load path from the roof truss to the foundations, etc. Any deviation from these rules can lead to local weaknesses where seismic forces will be concentrated, thus causing fatal damage.

These ideas have been turned into norms in the book of Eurocode 8. The design code warns in particular against irregularities in plan and irregularities in height, as well as against soft stories, torsional eccentricities, and the distribution of mass in a large number of modes during earthquake vibrations, etc. The idea in this case is clear: during an earthquake, the building must behave as a whole, with all its parts coping with the vibrations in synchrony with each other. Discontinuity and asymmetry disrupt this unity, creating points of failure, where inertial forces cannot be transferred efficiently to the foundations. [21]

Apostolis Konstantinidis, in *Earthquake Resistant Buildings*, presents a similar approach. He identifies soft stories, which are floors with a significantly lower stiffness than the floors above them, as particularly problematic, since they behave like hinges under seismic loads. Because of this behavior, deflections are concentrated at only one floor and collapse

becomes more likely. He warns against planted columns, which are columns that stop at a floor and do not continue to the floors below. He also opposes irregularities because, in his opinion, they weaken the integrity of the structure and its behavior against seismic forces. [22]

The validity of these calls for this type of formalism is reinforced by decades of earthquake damage reports. After the Kobe earthquake in 1995, the main reason for the fatalities of many structures was reported to be soft-story collapse caused by the opening of spaces on the first floors in order to provide more parking. After the 2009 L'Aquila earthquake, reports blamed torsional failure because it was observed that many of the destroyed buildings had asymmetrical plans. Under the same conditions, they were more damaged than buildings with symmetrical plans.

The principle raised is clear: seismic structural formalism is not simply a philosophy of rational design; it is a response dictated by scientific reasons to better withstand earthquakes. Although architectural ambitions often value complexity, in seismic regions, the best forms are regular, with continuity of the structure in verticality and symmetry.

However, many of the structures that have withstood the test of time are neither regular in plan nor symmetrical. Even the formalism dictated by design codes to resist seismic loads is not in fact the best structural form against these loads. The examples that design codes suggest involve straight structural elements. But the best form against seismic forces is in fact the tapered cylinder, where the planes are always circles and gradually become smaller with increasing height. Such an ideal structural form would require curved beams. Nevertheless, curved beams are still very rare in structural design, and buildings with shapes like the tapered cylinder are even rarer. Does this mean that structural designers do not follow by heart the design principles that they are committed to and have accepted as values? Moreover, why are we so obsessed with the use of straight lines in construction?

Structural forms underwent their greatest transformation with the Industrial Revolution and the “Henry Ford syndrome”, where the arch became a straight line. At that time, the principles of earthquake-resistant form had not yet been established, so there must have been other reasons for these fundamental changes in structural forms.

For hundreds of years, architects, engineers, manufacturers, construction firms, developers, and governments had been searching for a building that was cheap, durable, attractive, and capable of being produced by industrial processes. From steel mill owner C. D. Young's declaration in the 1850s that his three-story houses could be mass-replicated to Richard Buckminster Fuller's eulogy for the technology that made it possible to produce a completely fabricated house, designers were captivated by the dream of mass-produced houses. [23] The

vortex of the Industrial Age first swept away the minds and hearts of designers, and then changed the values and methodologies of structural design.

As for design values, it took almost a century after C. D. Young's declaration that architects and designers began to question the old values and search for other values that were in line with the spirit of the time. Walter Gropius and the Bauhaus workshops between 1919 and 1928 undertook this visionary act. However, at first, at Bauhaus, Gropius did not address problems of structural design, except tangentially through his professional office. [23] Nor were problems of structural fabrication. The two fundamental concepts that Gropius dealt with at the Bauhaus were the connection between art and industry and the standardization of dimensional and typological norms. [23]

Standardization was very important for the time, as Gropius said, in order to explore the effectiveness of machines as devices for the mass production of products "that are cheaper and better than those manufactured by hand." [23]

As Gropius explains, the principle of site work was to use the same people for the same stages of construction on each block of houses, thus increasing production. In order to ensure the interlocking of the different stages of construction, he continues, it was necessary to draw up a precise schedule of works, similar to those used for railroads. [23]

The workshops at the Bauhaus did not use fabrication. All work was done on site, generally using traditional methods. However, it was an industrial form of construction, with the organization of site operations as a real work process conceived as a work plan in a factory. There were concepts of standardization, mass production, mechanization of processes, specialization of the workforce, and a rigorous planning of materials and labor, all of which are characteristic of the industrial system.

The embrace of structural principles in Gropius' vision would be seen later, in the construction of the Deutscher Werkbund model, 1926-29, Stuttgart. [23] The planned module followed a structural grid, and all internal partitions were located on grid lines. It is clear that Gropius has a richer understanding in this case of design principles that are guided by the acceptance of the principles of modular structure.

In a paper from 1927, he reflects on the values of design when he writes:

The ultimate objective of this trend will be accomplished only when all the reasonable wishes of the individual for his home can be fulfilled without sacrificing the economic advantages of mass production. The houses and their furnishings will differ in their general appearance to suit the number and kind of their inhabitants. On the other hand, the components from which these buildings will be made will be identical. The "type"

itself is no obstacle to cultural development; on the contrary, it is almost one of its prerequisites... (Gropius, 1927) [23]

According to Gilbert Herbert, the following are the main points of his interest: (1) the optimization of dwelling design, based on generalized studies of user requirements, (2) the maximum exploitation of new materials and techniques of pre-fabrication, manufactures according to agreed norms and standards, (3) the study of the efficiency of building site, with respect to materials, and estimating procedures, and (4) a revision of building legislation to permit the exploitation of new technological developments. It was the same vision that Buckminster Fuller had when he designed the Dymaxion house. However, while Buckminster Fuller wanted to pre-fabricate the entire product, Gropius was reluctant to do so. He rejected complete prefabrication as an idea as it seemed to be contrary to his principles. Furthermore, for him, prefabrication played a negative role in achieving his goal of integrating art with everyday human life. As Herbert argues, the total prefabrication of the structure was for Gropius a product of a purely mechanical world. [23] The purpose of prefabrication, according to him, was to provide a certain measurable value in response to a demand expressed in numerical terms. As such, it would produce structures only for statistical purposes, not to express the rich diversity that construction reflects a human matter. The unity produced by such methods would be an imposed unity, ignoring free choice and individual preferences. [23]

Gropius therefore chooses the alternative of standardizing part of the process instead of the entire construction process, thus leaving room for the individual requirements of the users of these structures as well as room for the ideas and creative skills of the designers.

These standard elements were made out of necessity and were reduced from three-dimensional elements to one or two-dimensional elements. The reason for this is clear: the fewer parameters the elements had, the more easily they and the processes associated with their construction could be standardized.

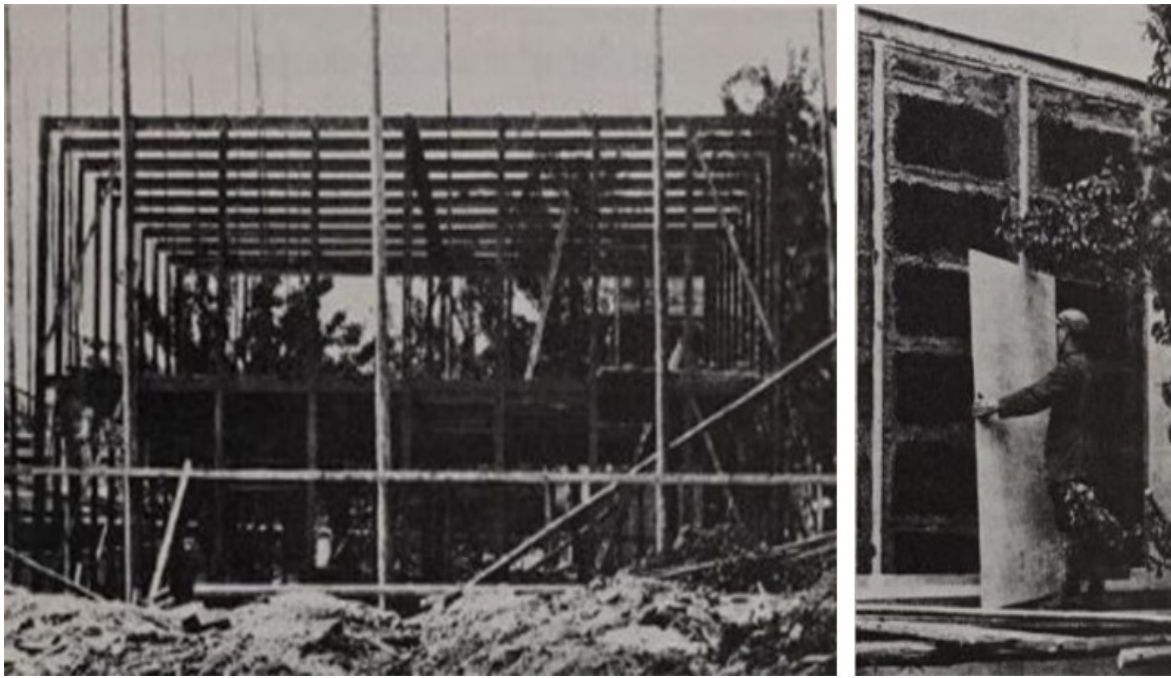


Figure 14 - Walter Gropius, prefabricated house, Weissenhofsiedlung, Stuttgart, 1927, construction details (adapted from Herbert, 1984, p. 59)

As for Buckminster Fuller's dream of a completely prefabricated structure for houses, it would be followed by another designer of that time, Gropius's compatriot; Konrad Wachsmann.

Like Gropius, Wachsmann chose to standardize the components of the structure, not the entire structure. However, unlike Gropius, Wachsmann achieved in practice the goal that his compatriot had wanted to achieve since 1910, which was to standardize the parts and have an infinite number of variations of the whole.

"I developed new types of catalogs", says Wachsmann, "which I believe for the first time in Europe did not offer finished buildings but instead all components to build with. Modular grids had been printed in those catalogs in which clients could draw their own approximate floor plans." [23] These sketches were later converted into professional plans by his office, relying exclusively on numbered, predesigned components to assemble the entire structure. [23]

One of the first examples of the use of these structures was in Palestine around 1933, where Gropius and Wachsmann collaborated. Conditions in Palestine favored rapid housing since, as Herbert mentions, "housing position had already been critical for some years, especially in urban areas, where an occupancy of 2.3 persons per room was further aggravated by the poor, often improvised, condition of the housing stock." [23] For the operation to supply clients from Europe to Palestine with houses with standard structures to be put into operation, as Gropius puts it, two conditions had to be met: they had to have good and flexible relations with the local authorities and they had to involve the local workforce as much as possible.

This operation was a real success, and not only they but also other design firms embraced this challenge with innovative solutions for the time.

The Copper Houses, as the buildings designed by Gropius and Wachsmann were called, consisted of large panels that were assembled together (fig.15).

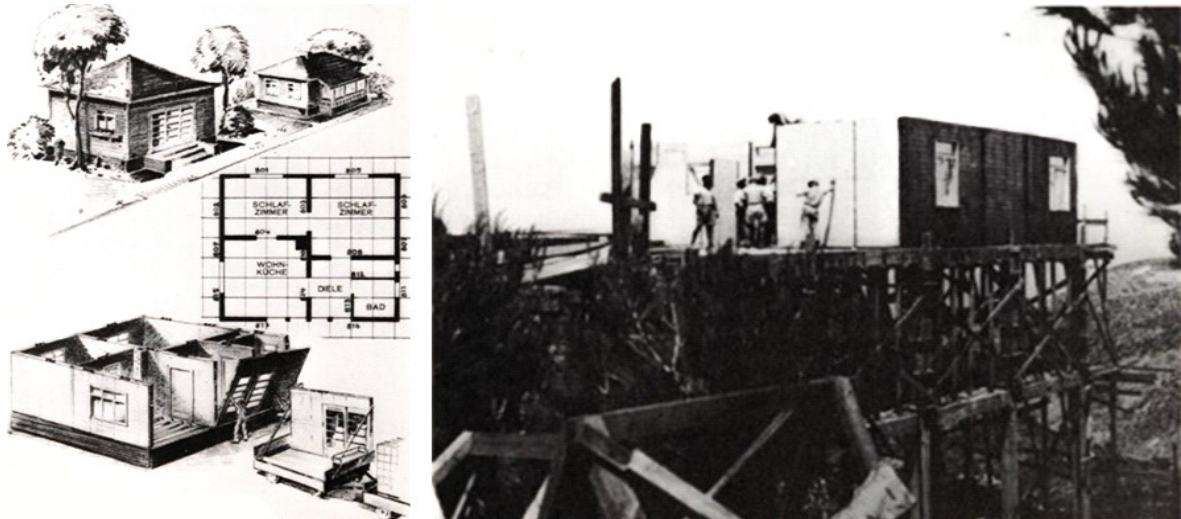


Figure 15 - Hirsch Kupfer-und Messingwerke, erection procedure, Copper House, 1931 and Deutsche Kupferhaus Gesellschaft, Tuchler house, Haifa, construction photo, 1934 (adapted from Herbert, 1984, p. 116-173)

Another steel truss-column frame system designed by architect Dov Kuzinsky, using the Böhler system, was used for the construction of at least three buildings in the region. One of them was built for Dr. Walter Katz in Rehavia in 1937 (fig.16).

These structures were among the first to use the bolted steel beam-column system in Europe. Structurally, they were among the first instances of frames capable of withstanding bending moments with the coordinate grid being their guidance. As pilot projects, they were not without reason met with doubts by many of their occupants. However, time has shown that these structures had satisfactory durability and comfort.

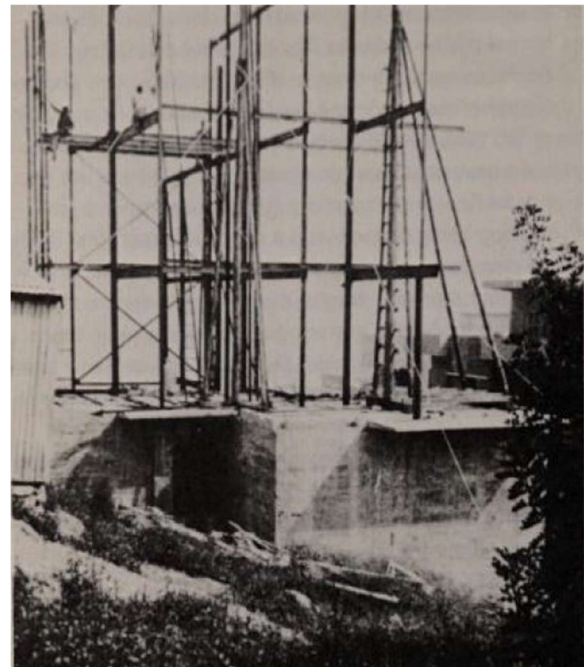


Figure 16 - Kalitzky dhe Entin, Levin building, using Böhler system, Haifa, construction photo, 1937 (adapted from Herbert, 1984, p. 188)

Herbert observes that, looking back at the later history of the Copper Houses in Palestine—their lasting durability, comfort, and even the fondness many occupants still feel for them—it becomes clear that the early caution was excessive, the doubts unfounded, and the judgment mistaken. Yet, he concedes, this is only the wisdom of hindsight, almost fifty years after the fact. [23]

The houses are similar to each other, but not identical, which shows the flexibility of the system. From Herbert's study, fifty years after their construction, he praised them for their good condition and their sufficient strength, although they had undergone various changes from time to time during their use, such as roof replacements or modifications of the interior spaces.

Then the supply of prefabricated houses from Germany to Palestine was interrupted with the rise to power of the Nazis and the outbreak of war. Gropius and Wachsmann were both forced to leave Germany and later collaborate in the USA again on the prefabricated house project, which they called The Packaged House. Nazism, on the other hand, opposed modernism, calling it against life, and embraced vernacular architecture. Gilbert Herbert, in his book *"The Dream of the Factory-Made House"* cites these fragments from newspapers of that time:

"...The new dwelling is an instrument for the destruction of the family and the race." [23]

"To oppose 'Bolshevist' urban architecture, Nazism must encourage young architects to create an architecture based upon 'nature and soil', using Handwerk rather than machine technology." [23]

In July of 1931, in a long article on the Reichforschungsgesellschaft, the paper [the *Völkischer Beobachter*] devoted several columns of invective to the members of the Jewish-Bolshevist architectural organization, the Ring and promised that the party would "settle accounts" with these men when it came to power." [Note: Wachsmann and Hirsch, who pioneered the prefab project, were Jews] [23]

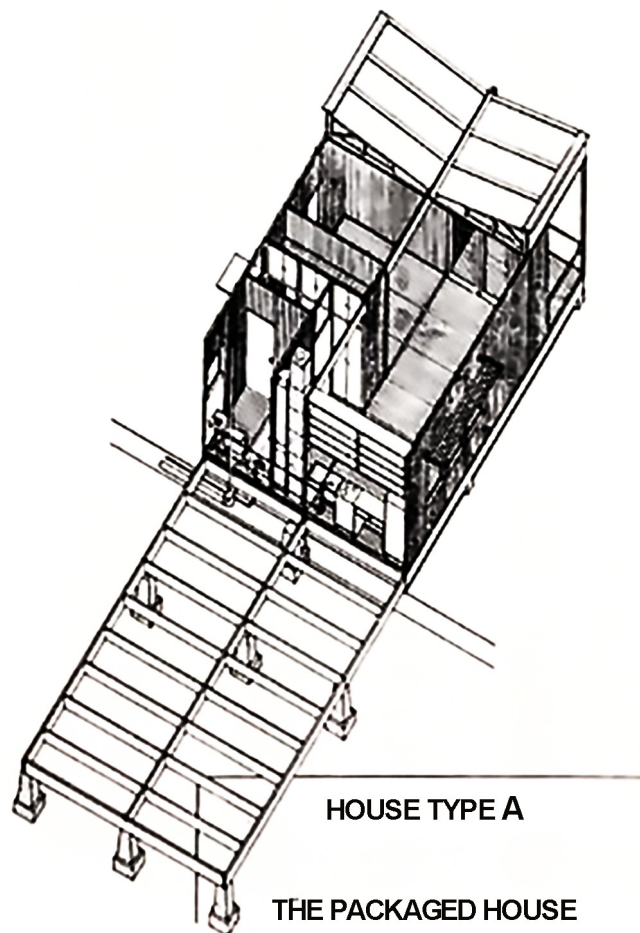


Figure 17 - Gropius and Wachsmann, Packaged House, standard house type A, 1942 (adapted from Herbert, 1984, p. 261)

In the Packaged House project (fig.17), we see that the designers favored the framed system with beams, as well as the design of the foundations with isolated footings connected together with continuous beams. The terrace was designed flat, also consisting of main beams and secondary beams. This project was better and more complete than the project of the Copper Houses that were sent to Palestine. However, even in the USA, despite the great work of the designers, the prefabricated house project had its own problems.

Mass-production houses, as in the case of Palestine, were seen more than a solution in cases of crisis. In addition to this thought, another assumption was that standardized manufactured houses would significantly reduce the cost of houses. R. B. White challenges this assumption, arguing that experience shows the belief in lower costs automatically resulting from mass production, standardization, and prefabrication of houses to be largely illusory. The necessary conditions for such outcomes have not consistently aligned to justify the claim. In fact, when looking at this country in particular, experiments with alternative building methods have demonstrated, if anything, that so-called “traditional” approaches—especially in house construction—continue to enjoy broad support. [23]

Sales were very low not simply because of people's resistance due to doubts about the new product, but because of the high cost. This went beyond all expectations that the industrial product would have huge savings (15 percent "across the board"). Another reason for the failure of prefabricated houses in the market was that the methodologies for their design were terribly time-consuming, so much so that they missed the opportunity to capture the new spirit that came at that time. As Herbert explains in this part, in a sense the high quality of the product held the seeds of its failure. Hindered several times by constant redesign, in the continuous search for even better technical solutions, accompanied by a perfectionist approach to project documentation, by a tendency to test and conduct experiments with physical models, by the fixation on thinking through every possible detail of the house instead of providing general solutions, having delays at every stage because of the search for the ideal, it took an extraordinarily long time to move from the initial phase to the final phase of receiving the product. [23] This entire protracted process resulted in a loss of cost, time and resources, and the consequences were catastrophic for their design firms.

Here too, we see that the factors that led to the developments and failures of structures are not scientific reasons, but are, as Herbert also mentions, mainly social, economic and political factors. This case is a good representative that raises the concern that the best solutions of structural forms are sometimes prone to failure not because of their characteristics in scientific terms, but because of influences that come from outside the field of construction. Herbert again, when describing this failure of prefabricated houses, does not leave this fact unmentioned: "The factory-made house is a product; industrialized housing is a process. In that process there are of necessity other sub-systems, relating production to distribution, financing, legislation, transport, and land." He notes that the Packaged House, understood purely as a manufactured product, failed to account for this broader framework. [23]

Regarding the aesthetic forms of structures:

It is clear that structures that distribute loads uniformly are not always beautiful. For example, the thickness of an arch designed to support its own weight must increase considerably near its supports. Such a form is the result of structural accuracy, but many artists may choose the arch of constant thickness as more attractive. Moreover, even the eye of an expert cannot sometimes distinguish the exact distribution of loads in the structure and, consequently, most who encounter the structure have no way of appreciating it.

According to Torroja, the most important aspect of the aesthetic problem is to evaluate the visual aspect of a structure in relation to its surroundings rather than its geometry.

Next, I will give some of his ideas regarding this approach:

Before building the structure, the effects of perspective and light-shadows should be studied. For example, there is very little aesthetic value in an arch if there is no point below it where we can stand and admire it. The shadows of the consoles of a deck projected onto the arch, cut the contour of the latter unpleasantly. The other lines and planes that surround it influence the entire appearance of a straight line, a curve, or a surface or volume. For example, a straight line of a connecting tie in an arch may appear to be a curve. In this case, the convexity that the line creates above the arch may seem to contradict it. A rectangle placed inside a cup has a distorted shape. The apparent brightness of a beam can be increased if its section is such as to create a longitudinal line of its own shadow. Other similar examples abound. Even the ancient Greeks, who were masters of the study of optical sensation, carefully studied and repositioned the columns in their temples in such a way as to improve the aesthetic aspect and the rhythm created by the perspective of the columns. [3]

He also gives his opinion on the aesthetics of geometric forms in construction:

Architecture has often tried to avoid curves, not only because they present problems in construction and have high costs but also because of the difficulties in acclimating the eye to the continuity of these lines. The curve has its own personality and finds it difficult to adapt it to the role of a secondary element that connects two main straight lines in a structure. A curve has a spontaneous nature and consequently dies when artists try to create it by force. [3] Torroja, therefore, prefers to replace it with the visible interruption of an angle. He considers the angle not only the simplest but also the most suitable. According to him, it is the main tool used to show two different directions. He values the angle for the personality and singularity it offers. And of all angles, the right angle is the most favored, since it has the most special personality. [3]

The right angle will not brook any additions or subtractions, it will not pardon the errors made in tracing it. It is as hard as exact truth. The network of vertical and horizontal lines, crossing at right angles, has by itself defined a style: the English perpendicular. The quality of right angles is also evident when curves intersect each other, and meet orthogonally. Two families of geometrical curves, mutually orthogonal, form an expressive pattern, rich in its content of perfection. (Torroja, 1962) [3]

Then he lists all the forms that for him are the best examples and the artist should know and use them both in construction and as decorations. They are “radii and concentric circles, bipolar circumferences, homofocal ellipses and hyperbolas, logarithmic spirals, rosettes of lemniscata”. [3] He especially praises the beauty of the arched forms that collide with each other at right angles created by ancient Viking and Celtic artists, which remind him of seagulls in flight. These forms, according to him, are ideal and require no improvement. Straight lines, in contrast, are much more sensitive to the influence of any other line interacting with them in the same field of view. Some improvements in these interactions came from the ancient Greeks. One of their achievements was especially in giving the exact

impression of straightness. As soon as straight lines happen to be combined with curves, the straight lines suffer. The optical illusion distorts them. An example of such is the braced arch. Bracing, being straight, requires a curvature, however slight, in the direction of the arch to look better. [3]

Regarding the sincerity of structural form:

Torroja also states the idea of achieving structural forms that express the process of their construction and the way structures work against gravity. He also demands that the structure be as visible as possible. He writes that it would be dishonest to manipulate wall coverings to imply a structural system different from the actual one. Such insincerity becomes a grave falsehood if the visible expression of the load-bearing structure is intentionally shaped in ways that contradict the principles of stability and strength, or even if it is simply inconsistent with the material exposed to view. [3]

For example, it would be false for him to cover reinforced concrete beams with stone cladding, thus deceiving the user as if the structure working in flexure was made of stone. In addition, it would be an even more wicked act if decorative stone arches were supported by simple columns, which are normally incapable of withstanding the lateral thrust of an arch. In such cases, what Torroja considers worse than falsehood in itself is the feeling that someone has tried to deceive us and abuse our innocence.

As for the role of gravity in structural aesthetics, many architects and structural designers have appreciated it. Torroja himself mentions this as a value in design, saying: “There is nothing so congenial in the architecture of all times as the horizontality of floors and the verticality of gravity.” [3] Juhani Pallasmaa also appreciates the importance of gravity in the aesthetic expression of structures when he argues that gravity lies at the core of all structures, and that the most powerful ones heighten our awareness of both earth and verticality. While grounding us in the depth of the earth, they simultaneously awaken a desire for levitation and flight. [24]

Patrik Schumacher best describes this entire theory of structural formalization in modern classical structural design. He described it as supported by the ability to decompose a structure into distinct and clear components. [11] Each of these parts contains a standard concept, such as columns, beams, cantilevers, frames that work in bending, arches, vaults, domes, shells, and so on. This definition of elements is taken for granted: All of these concepts are characterized by clearly defined geometric shapes that depend mainly on the way they work under the action of loads. Each of these pieces can be combined into more complex systems such as beams in trusses, columns that expand and turn into shear walls, and so on. By dividing the structural parts in this way, it becomes simple to articulate the joints between them and to have control over the distribution of forces from top to bottom

to the foundation. This decomposition strategy is closely related to the strategy of uniformity of each system, thus penalizing any shape outside this format.

Nevertheless, within this format there remains a state of confusion that does little to support the claims of even the most prominent figures of design. Since their statements are often contradictory, one is left to question the validity of formalism itself. As long as Louis Kahn emphasizes the importance of symmetry in structure, while Frei Otto finds beauty and structural logic in asymmetry, we are left asking: Why must the structures be symmetrical? Who said they must be devoid of ornaments? Who said they must be full of ornaments? Every structure offers something. For every example that insists on a particular approach, I can find a counterexample that succeeds in doing the opposite. When Torroja says that beauty should be found in structural sincerity, Gordon confronts it by implying: “What are we to think about ‘honesty’ in design? Honesty compels me to say, ‘Not much.’” [17] Even Torroja himself is contradictory in his statements when he praises the beauty in structural continuity, for example, but then argues that aesthetic and structural performance are not always connected. [3]

This is not a rejection of those figures—they each had their own vision—but I cannot commit to a singular vision of formalism when the literature itself is so conflicted. It seems to me that structural formalism, as a concept in itself, does not resolve problems—it merely reframes them.

2.2 Contradictory Structural Design. The Case of Informal Networks

In addition to the traditional modern formalist approach, the recent history of structural design has also seen other alternative approaches that challenge the definition of clear and rational elements and forms. An example of this philosophy is Cecil Balmond's *Informal Networks*. "Informal" according to him represents the belief that we should not necessarily accept a fixed symmetry for structural frames, which represents his design values, and "Networks" to support the idea that a structure is an assembly of its parts brought together through patterns, which represents his method of design. An example of the application of this theory is around 1980, during the work that Balmond did with James Stirling in Stuttgart, on the pedestrian walkway in the Neue Staatsgalerie. For Balmond, this project is particularly important because, in addition to structural problems, it was the first time that he dealt with architectural problems. As a result, his experience in this project often involved discussions about spatial qualities and their values, which he of course defended using his engineering knowledge.

The exhibition space and the lecture space, as Stirling had conceived them, should not have columns.

However, Balmond argued that columns should be installed. This reason, according to him, did not come from pragmatic solutions—to make the engineer's life easier—but he felt that the space needed columns and made more sense this way considering what the space above it contained.

After some discussion, the designers accepted this change, and Stirling put the final touch on the columns, transforming their upper parts into shapes that Balmond called "ice cream cone columns." (fig.18)



Figure 18 - Exhibition stand, Dutch Telecom
(adapted from Yoshida, N, 2006, p. 170)

Then other colleagues suggested that he install expansion joints. The plan was about 110 m long by 100 m wide. Consequently, the factor of causing large residual stresses due to temperature changes, as well as structural displacements, was considerable. However, wherever he tried to specify an expansion joint, he had the feeling that the resulting appearance conflicted with the architecture. Therefore, he decided not to install them at all. Later he discovered that in fact the final additional cost of installing additional reinforcement to withstand these reinforcements was in fact almost the same as that of using expansion joints. From then on Balmond says that he learned not to take structural principles necessarily for granted, but to test them case by case. [7] For him, great figures of the time such as Pier Luigi Nervi and their rational philosophy did not meet the requirements of structures in an irrational reality. Instead of the precision of structural elements and the uniform distribution of loads, he preferred ambiguous forms, where different typologies were mixed, like a shear wall, a truncated dome, etc. [7]

Balmond expressed his rebellious spirit towards rational formalism while working on the construction of a house in Bordeaux in collaboration with Rem Koolhaas (fig.19). Both of them had the same opinion on this issue: “It is not structure in the uniform sense; it is not structure that distributes itself everywhere; it is structure that works in local conditions and does specific things.” [19] They often used structural forms as an architectural aspect to give a kind of motif in space. Balmond was particularly interested in the hybrid conditions of structures. For him, more interesting than regularity, was to express the concept of impure.



Figure 19 - House Bordeaux, France [25]

Again, the case that expresses this vision comes from the joint work with Balmond and Koolhaas, on the Seattle Public Library project in 2004 (fig.20). This project has three self-supporting boxes. There are very few other vertical supporting elements, only about eleven or twelve columns, which, considering the vast space, are insignificant. The tectonic boxes were supported with a thin wrap around to allow for satisfactory seismic performance. Balmond then played the “game” of balance between architectural expression and the

constraints of gravity, as he reinforced areas of the structure where the surface required additional strength and introduced props wherever gravity demanded support. These adjustments, he notes, endowed the space with great power, a sense of continuity, and moments of surprise as one moved through it. [19]

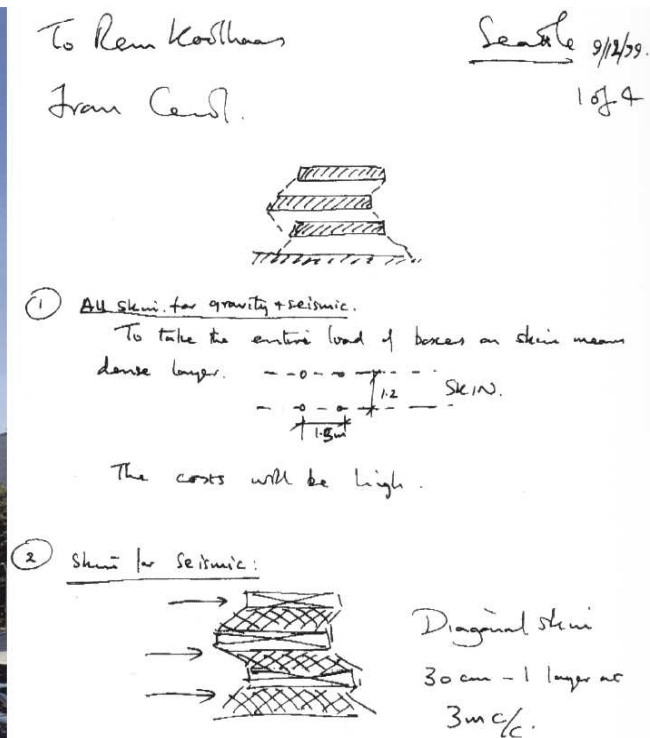
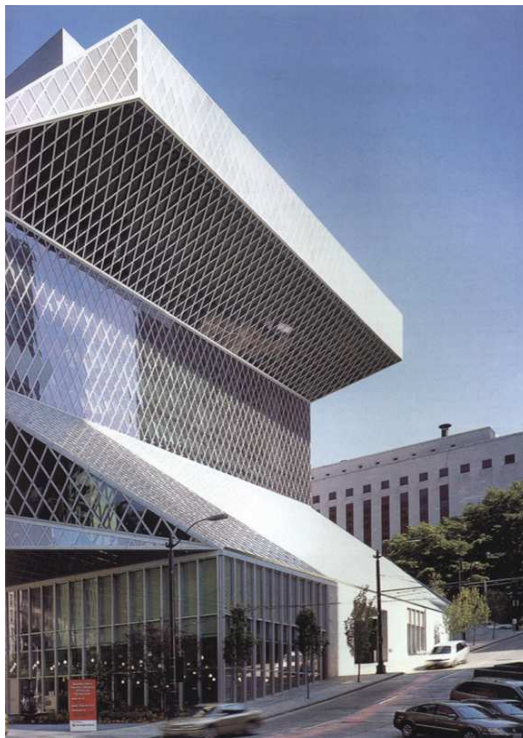


Figure 20 - Seattle Public Library, Washington [26]

However, Balmond does not welcome chaos. Instead, he seeks to find a solution in this irrational reality. The method he uses is brilliantly defined in his writing: "The idea of form emerging is a thing that really fascinates me: from a random start, how does it happen? It happens through control and continual feedback..." [7] He goes on by reflecting on his exploration of form, and explaining that by repeatedly drawing lines from half-points to third-points around a square, a complex spiraling web begins to take shape. Extending these lines suggests the potential for architectural form. He then imagines translating the geometry into material: each line becoming a 40 cm steel plate of 2 mm thickness, with the principal structural lines thickened to 5 cm. [7] By cutting away the corners, the abstract web transforms into a pavilion. This alternative formalism method was followed during the design of the pavilion for the Serpentine Gallery with architect Toyo Ito in 2002 (fig.21). Ito and Balmond decided to create movements of the structural parts and to keep track of the patterns of these movements and to repeat them. They placed aluminum and glass panels in the space and painted them white, alternating the positions of the panels and glass. [7]

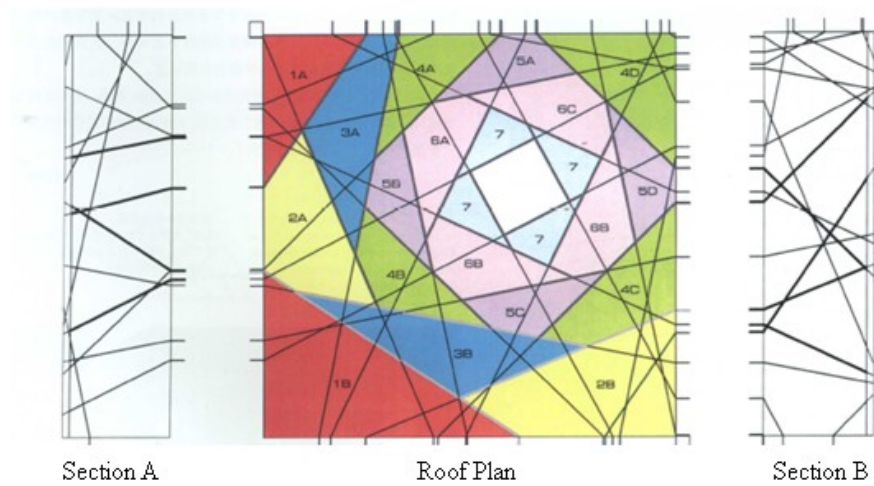


Figure 21 - Pavilion, Serpentine Gallery and its roof plan [26]

There was no element that was repeated twice. The total weight of the structure was fifty tons, which was a success, compared to the equivalent system with frame-and-columns that was supposed to be designed if it followed the standard design, which had a weight of fifty-two tons. [7] Also from the aesthetic side, Balmond says: “You had to appreciate the amazing aspects of a pattern that had been compiled and that had both an open and a closed nature. You could not second-guess it. It was a kind of meditation on geometry itself.” [7]

Also in the collaboration with Daniel Libeskind for the Victoria and Albert Museum project in London in 2003, they used a similar method for finding tiling patterns (fig.22). Balmond wanted to do something different from the method of placing tiling in a regular manner, something that seemed to move. He defined three tiles, which he named P, Q, and R. If you put them together, you can create an infinite plane. It looks the same in certain places, but in fact the pattern is not repeated anywhere. Just when you think you have found the repetition, a logical break occurs. That is a pattern that never repeats elements, ad infinitum. This kind of method was invented by mathematician Robert Ammann. [7] The secret of these patterns, called aperiodic, is the hidden pro-structural characteristic they have. Throughout the shape formed by the patterns, a hidden grid is created. Another important aspect of these patterns is that they can be enlarged or reduced to different degrees. Each of the tiles can be transformed into smaller Ps, Rs, and Qs. As a result, each tile has its own individual shape.

Balmond further developed the form of the patterns by moving fragments of the blocks of these patterns against each other, thus creating fractals. The product obtained from the use of these patterns is a branching, as if they were branches of a tree, where each branch multiplies until it reaches the formation of leaves. Consequently, playing with geometry, a solution emerges that is unprecedented and unforeseen.

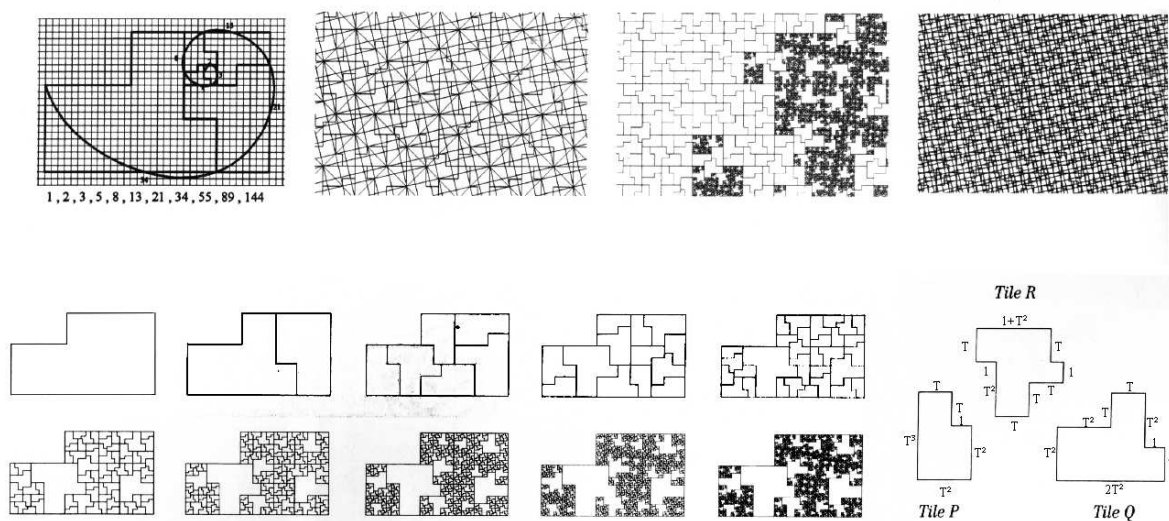


Figure 22 - Victoria and Albert Museum, London, drawings of tile shapes and computer drawing of tiles, fractal of tiles pattern, drawing of tile mathematics, diagram of tile shapes, embedded [26]

The tiling pattern can also be derived using the Fibonacci sequence, which is found in many phenomena in nature. A right triangle with sides 1 by 1 gives a hypotenuse equal to the square root of 2; If you add 1, you get the square root of 3. This is how people in ancient times calculated the square root. This sequence allows you to get a spiral from it (fig.23).

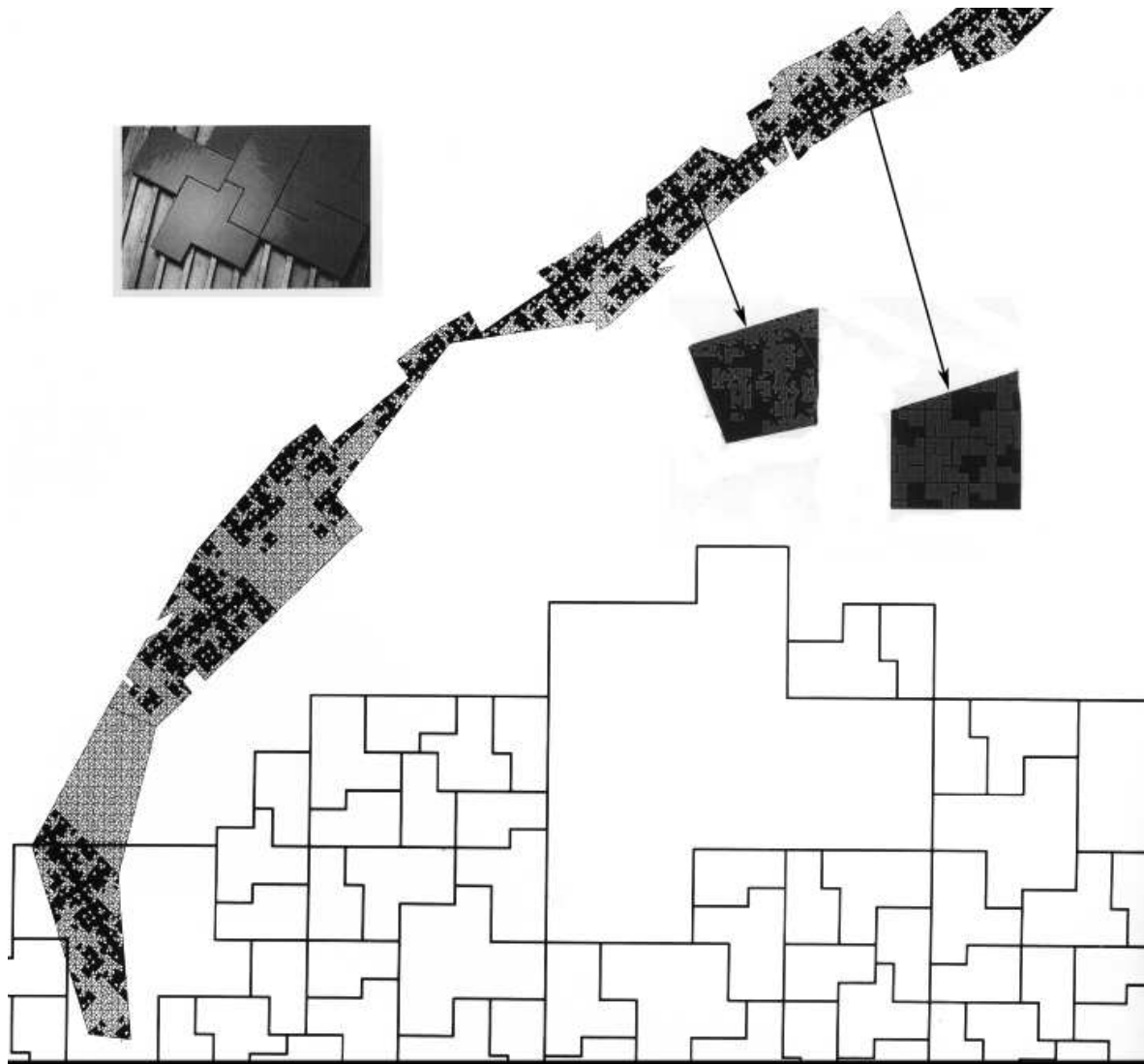


Figure 23 - Victoria and Albert Museum, London, schematic drawing with Fibonacci numbers [26]

As for generating patterns, Balmond initially tried to draw them himself using intuition for his projects. But with experience, he found out a free form cannot be drawn, as it always risks being clumsy. He prefers to use algorithms and perceive from them some rule with which he can create the form. As for Balmond's vision to move away from the rational, he expressed it once again in the project he did with Toyo Ito. Instead of straight columns, he repositioned them using a vector pattern rule. He called this solution “Dancing Columns” (fig.24). If you notice the movement of the columns, it was like a coding in process: The process was repeated and patterns were created. Even moments that seemed random were transformed to give a kind of order. If they were to adapt to the design of a building, let's say a multifunctional object, one could logically place the least deformed columns on the perimeter to produce the external shape of the structure. Then there was the facade, which was generated directly by processing the numbers. This process was entirely computer-based and what they obtained was a complete consequence of the numbers. However, the generated shapes were not without a rule. If the facade were to be prefabricated, then only six types of panels would be needed (fig.24). They also discovered an algorithm behind this pattern

(fig.24), and the whole process was like generating a DNA, with the exception that the latter is generated from four etalons. As long as this rule was followed, it could continue indefinitely and the overall shape would change, until they were satisfied with the shape and stopped the process itself. And yet, if the parts were prefabricated, only 6 panels would be needed.

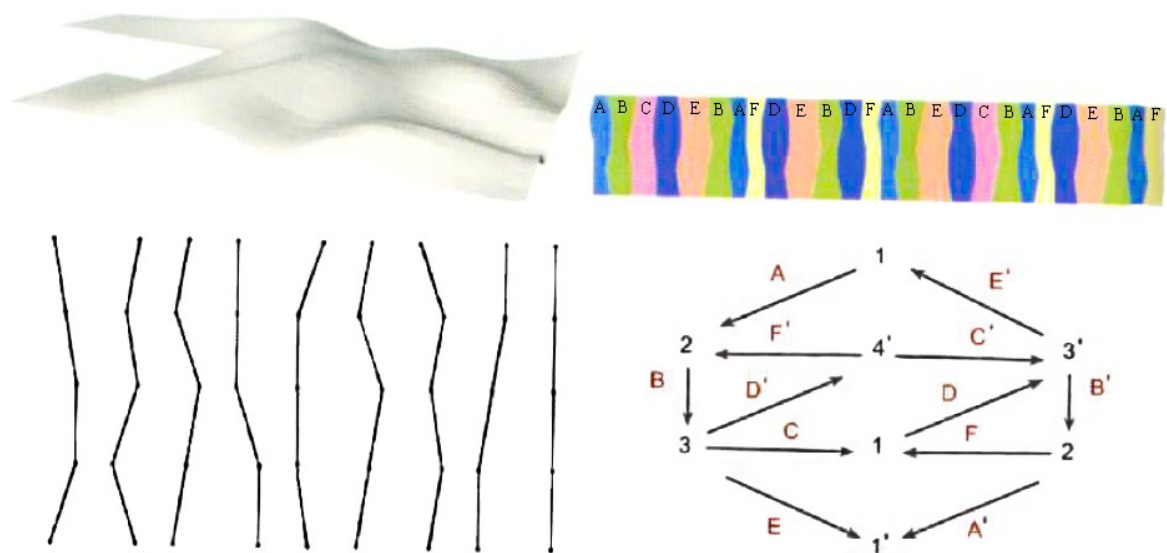


Figure 24 - Portuguese Pavilion, Hannover, Germany, drawing of column profiles, repetition of panels, algorithm for generating panels (adapted from Anderson, Balmond, Isler, & Billington, 2011, p. 62)

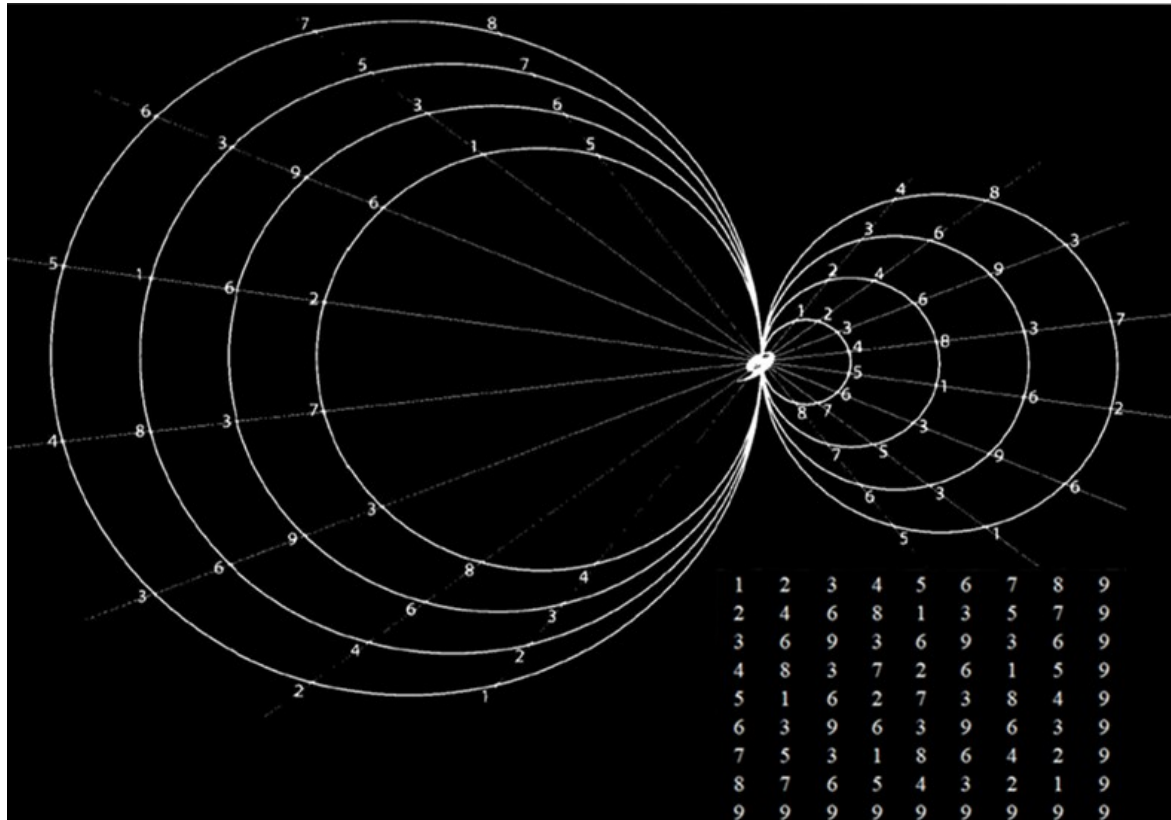


Figure 25 - Drawings of number grids and circular orbits, "Strange mandela", Cartesian plot of number sequence (adapted from Anderson, Balmond, Isler & Billington, 2011, p. 63)

Another example of his work is the study of number lines. He explains this in his book *Number 9*. [27] He reduced the products of multiplication to rows of single numbers (fig.25). From this, he found four patterns: the one times, two times, three times, and four times tables, which can be reversed. The two times is the inverse of seven, one is the inverse of eight. These numbers were then arranged in circular orbits (fig.25). Balmond also established another type of organization, which acted as a single point attractor (fig.25). He then translated these patterns into structures. As for the two-times table, it can create a kind of molecular structure, which Balmond used for a skyscraper in China and turned out to be a pretty resistant form. If you use the three-times table, you get the famous forms of Antoni Gaudí. Then if you use the whole field of numbers you will get even more strange shapes. And, of course, from all these arrangements of numbers, you can get structural shapes. For example, with just a few random points, two edges, and joining them with a form-finding software you can get minimal surfaces. They are all efficient shapes, but there is no way to find them using just pencil and paper. [27]

Balmond reflects that his career began within the inherited framework of the Cartesian world—a system we inhabit, rely on, and believe in. Over time, however, he recognized that reality is broader, more generic, and nonlinear, with Cartesian space representing only a limited subset. [19] “Trapped by a Cartesian cage I wanted to break out.” [19], he says.

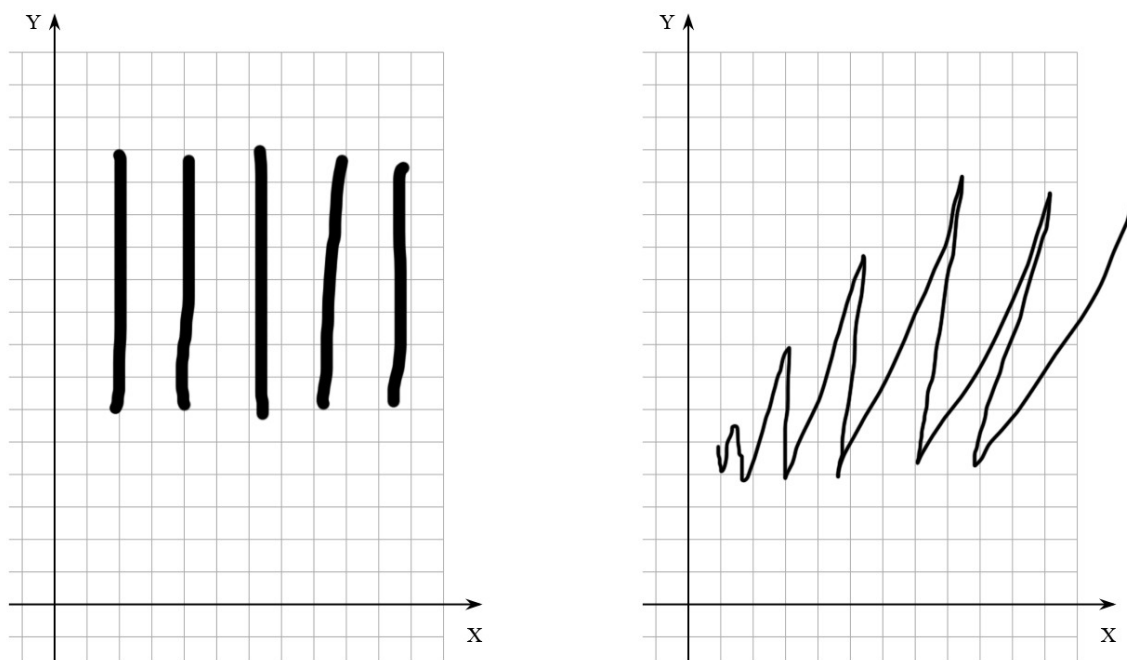


Figure 26 - Rra-ta-ta-tat instead of a 1-2-1-2 inside the Cartesian coordinate system

The conventional way of formalizing structures produces Phileban solids such as spheres or cubes, and the coordinate grid is based on these shapes. This system has dominated structural design since ancient Chinese and Egyptian architecture. Balmond with his alternative approach to formalization does not reject the traditional approach, but rather broadens the

understanding of structural design. Formal patterns may aim to be regular, such as creating spheres or equilateral figures, but most forms in reality have nonlinear behavior. Waves, heartbeats, or even the growth of galaxies show patterns of a fractal nature and are always in motion. Balmond's vision is not to posit a new norm of forms and reject old forms, but to create new forms of organization for structures spontaneously through the exploration of patterns. He refuses to take for granted the forms dictated by fixed rules. For him, the assumption that the structure should be placed as regularly as possible resembles soldiers marching in a parade. He opposes the regular cage and implies that he wants to break out. He also rejects the reduction of forms to only vertical and horizontal elements. He seeks to break out of this stifling paradigm. “Have a syncopation—rat-ta-ta-tat—instead of the dull metronomic one-two repeat of post and beam that rises up and runs along our buildings in stark structural skeletons.” [19], he says.

For him, structure does not need to be explicit and comprehensible. There is no reason for structure to be simply a functional skeleton or a manifesto of calculations. On the contrary, it can be more sensitive and more communicative with its surroundings. He values ambiguous structures, like puzzles, that provoke the mind.

Moreover, Balmond does not take structural sincerity for granted. For him, the problem with this approach is that by justifying it as sincere, the structure comes across as dull. Such configurations seem to say: “I am machine, I am reduced skeleton”. Instead, Balmond proposes a medium that is neither a structural aggression that dominates space nor an ordinary skeleton, and for this to happen technology must take on a different role.



Figure 27 - Kunsthal Rotterdam, three columns [28]

Before you enter the Kunsthal, Rotterdam, notice three columns next to each other (fig.27). They are different in shape and material, one is made of concrete, the other two are made of steel. The concrete column has a circular section, and the steel columns have different profiles. One has an I-profile, while the other is castellated. These profiles are common in various buildings, but what makes this case unusual is their presence next to each other that somehow disturbs the air. Each has its own personality that collides in a space. Above them, each has a slab that is independent of the other that unloads the loads on the columns, which act as single supports. This idea of the structure gives the space an additional value. "Imagine a regular spacing to the columns...", says Balmond, "There would be nothing left, no animation, no off-beat pulse. The juxtaposition brings in its own drama, and the mix urges entry, to by-pass the inconsistency for more settled regions, within." [19] The structure presents itself not as a skeleton without expression but as a series of provocations. Sometimes it appears awkward, sometimes as solid form. "Delight, surprise, ambiguity are typical responses", [19], says Balmond. And indeed, uniformity is broken and balance is disturbed. The demand for order, in the sense of its total dominance, is called into question.

The difference between the rational and the irrational can be compared to the description of forces. Newton proposed the classical approach: force as action and distance as a straight line. Determinism has manifested force as an arrow, straight, presenting a linearity, a chain of rigid and absolute solutions. However, between a point A and B there is an infinite zone of possibilities. There no need for distinct rules, and fixed patterns, which would have to be copied blindly. If there is a rhythm, it is hidden in the potential possibilities and the connections between them, which are not necessarily clear at first. The rule, in the determinative and hierarchical sense, departs from the way reality works. Actions can start small, and then multiply, spreading to form the whole. There can also be overlaps, mixing of ideas, which are acceptable in Balmond's view of design.

In the case of rational formalization, however, the exact opposite happens. It is rigid, hierarchical. Its characteristic is analysis through references, relying on previous forms. Structural space in this case is seen as a container, without expression. The process does not take risks. To design a structure in this way, it is enough to apply technical principles, which produce both the structure as a whole and its parts down to the details. Since they are based on previous references, the derived forms are predictable and presumably efficient. This is also the reason why structural designers are so confident in using this approach and at the same time so confident in their design.

Following this format has not many alternatives. We try to capture the chaos and convert it according to our principles. We try to eliminate the "flaws" and ambiguities. And according to Balmond, we try hard, but the conversion turns into heavy formality and dullness. [19] A lighter approach is what Balmond suggests. He wants to consider chaos as a mix of several states of order. What is perceived as improvisation is in fact a kernel of stability, which is

slowly derived into another state of order. There are also parallel equilibriums, which exercise their jurisdiction over the structure. Simultaneity is in fact what matters, not hierarchy. According to Balmond, the structure should not be seen as a framework, but as a generated diagram. [19] Instead of lines connecting two points, the new program provides single threads that are repeated and twisted to create configurations. Therefore, instead of an orthodox design, it turns into an improvisational design. As for the use of technology, normally the traditional spirit is to use the computer to analyze standard shapes and to produce project sheets with CAD. Balmond proposes a different way of using the computer. Using the power of algorithms, he uses a trial-and-error approach to find shapes. You can put the constraints of the shape in the script and let it explore possibilities that are impossible to imagine using the drawing technique alone. [19]

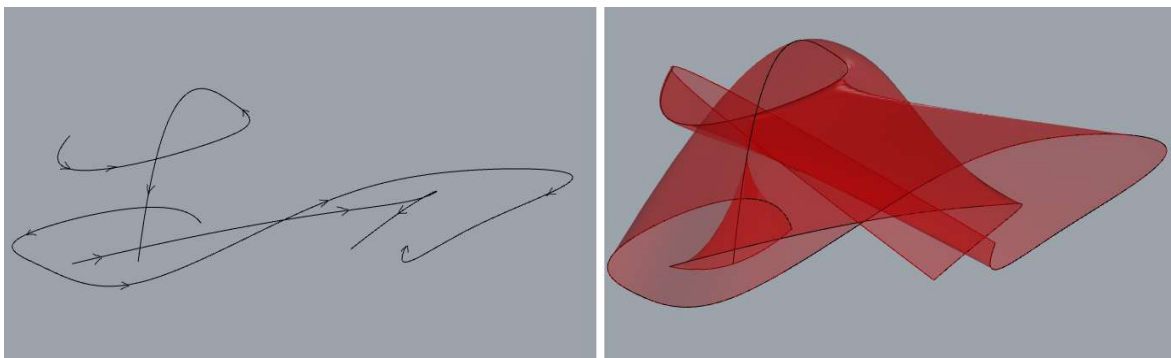


Figure 28 - Free-form using curves

Free-form techniques have also begun to be used for structures (fig.28). The forms created are not only attractive to the eye, but also achieve their supporting function.

Lastly, Balmond does not leave without mentioning the interaction of different actors and the potential of the structure beyond structural performance. Because the building is a structure, there must be a kind of certainty; because the building is architecture, there must be a kind of unpredictability. The structure should not be forced into the building. Instead, as he suggests, it can be an opportunity to express both of these states. [19]

2.3 Contingency in Structural Design and Why Things Fall Down

During the master's degree in architecture at the Polytechnic University of Tirana, students have a joke they tell among themselves, regarding the structural design. “If they ask you, ‘How did you solve the structure?’ say, ‘With spatial truss, professor.’” This is the answer that gets them out of trouble and which they play with later in their profession. And indeed, spatial trusses or steel structures solve awkward situations inside and outside the auditoriums.

In the case of the building that resembles the head of Skanderbeg, the Albanian national hero, in Tirana (expect this passage to get even more awkward), the project engineer is explaining to us that there had been delays in issuing the building permit for a piece of land where a part of the project was supposed to be built (fig.29). He then went on to say that the main problem, as strange as it may seem, was that Skanderbeg’s ‘shoulder’ was supposed to be built on that problematic land. And, although in other similar cases, the project could be modified, in this case it was absolutely impossible to leave Skanderbeg without a shoulder. Consequently, the solution came out to be a light steel spatial truss that came out as a cantilever from the rest of the structure, like a parasitic structure. It worked.



Figure 29 - Skanderbeg Head Building, spatial truss for “Skanderbeg’s shoulder”

The Sagrada Família, on the other hand, is asymmetrical, and unfinished. It has been like that, with the “under construction” status, for almost a century and a half, longer than what would be considered a normal lifespan for structures. Yet it is considered a wonder of the world for its ambitious design.

Also, most of the house structures in Albania have rebar exposed above the terraces in the hope that in the future another floor will be added (fig.30). The designer in this case, whether

he is an engineer or, as is usually the case, the house's resident himself, is aware of this potential change and has taken this into account at the beginning of construction, making the structure potentially capable of supporting more floors than it actually does. However, many years may pass until it does and in many cases the structure may spend its entire life in that form, as an attempt to reach its potential.



Figure 30 - Bars and unfinished structures over terraces (author, 2025)

Another case of structural contingency is the change of structural design methods for houses from the masonry structures that were previously widely used in Albania to reinforced concrete frame structures. The reasons are entirely cultural. They are not economic reasons, because masonry is cheaper than frame structures for low-rise buildings. Both of these systems can cover common spans in the case of houses, and both can carry common loads in the case of houses. Moreover the construction time and the constructability favors the use of masonry structures. Yet, after 1990, with the fall of the communist system in Albania, the new spirit sought to build like the advanced western world, so Albanians began to use new materials and considered their use as “higher quality of construction”, and the use of masonry as inferior.

As for construction in Albania, there are countless examples that require solutions to the problems with land properties, which, of course, influence the way in which structures are built. In Astir, Tiranë, I was curious about a wall that is half built with concrete blocks, half built with reinforced concrete. When I asked the owner, he said that the part with reinforced concrete is higher and therefore should be more resistant. What he does not want to say is that he has legal problems with the land usage and has thought that the part of the wall, which he will probably have to demolish later, should be built with concrete blocks, so that its demolition would not cost him much. The choice of material in this case has nothing to do with the bearing capacity of the wall. Simply, in this case, the reinforced concrete part is more difficult to collapse, since the equipment to cut the concrete and the reinforcement costs more and requires specialized labor.

Similar cases of contingency in construction are numerous, and the most successful engineers are those who, first of all, do not turn a blind eye and face these situations, and secondly, provide solutions. Nevertheless, contingency is a phenomenon that accompanies construction throughout all its stages. Structural design is deeply dependent on other forces outside the profession and science, which turn design into a social activity. To begin with, the concept of failure actually varies according to the case. A structure can be considered as if it is not a failure during an earthquake as long as all people inside and outside it are not injured, despite the fact that the structure may have to collapse or be restored later. For other structures, such as those of hospitals, non-failure means being able to be used directly after an earthquake, i.e. they should neither suffer large residual deformations, nor weaken, nor lose its function. Even in the case of automobiles, for example, they are designed to avoid accidents and yet, they are also designed to protect human life in the event of an accident by absorbing the damage itself.

Another design requirement is that the building needs to be safe during its life. In the case of Oliver Wendell Holmes book [29], one-hoss shay was built to last 100 years and collapsed after that many years, no more, no less. However, this is impossible to assume for structures. It is impossible to predict exactly how long a structure will last before it collapses. Consequently, instead of this, there are general predictions that depend on the material and the structural system used, but these predictions are of course, to a great extent, approximate. We can only consider the problems of bearing capacity in statistical terms. Consequently, when we design a structure in practice for a normal life span, we must also accept that there are some risks, however small, that the structure will fail before the time specified as its life span. The statistical approach has also arisen because of the impossibility of a complete and accurate theory of structures. Although we assume that the bearing capacity and the loads have a certain value, neither of them has the assumed value throughout the entire volume of the structure, at all times.

There are also risks that are possible but so unlikely to occur that they are not worth considering in the design. In Spain, for example, structural designers do not design for earthquakes. Similarly, there are only a few special buildings such as those of administration, the military and those of high importance that are designed against explosions. Although there may be a correct answer to an analysis, design does not have a definitive answer, there are only better and worse answers. In this situation, the computer can explore swiftly the different alternatives and quantify some of the pros and cons of the possible options.

Other cases of contingency in design also come from design methods, which are treated as infallible and unquestionable. The dome of Saint Peter's in Rome was unable to support the tensile forces acting on its horizontal sides, due to its shape. As a result, it later became necessary to reinforce it with iron rings. These rings were reinforced again later. All these reinforcements are not visible and their existence was hidden by its architect. So, the shape

of the dome actually deceives the observer by showing that it is self-supporting while its form does not respond to structural needs. Michelangelo was aware that this shape was a weak point in terms of structural performance. The design method at that time dictated him to look for another form, but he did not hesitate to ignore the method and design the dome that way, although he later added stiffeners to cover this problem. Yet, as Torroja puts it in this case, “that does not detract from the beauty of the cupola.” [3] So, apart from apparent errors in the application of the design methods of that time, the dome of Saint Peter is considered a success in design.



Figure 31 - Tower of Pisa (author, 2023)

The Leaning Tower of Pisa is another example of how contingencies and flaws during the design have actually led to success (fig.31). It was originally conceived as a vertical tower, but its foundations, due to the different layered formations of the base, suffered differential settlements. As a result, the tower shifted and created the appearance for which it is known today. The differential settlement, which was initially considered a failure of the system, later became the main characteristic of the identity of this structure, attracting millions of visitors every year precisely because of this characteristic.

The problems of bearing capacity and stability, as discussed above, are not well defined. The same can be said for the problems related to durability. Such problems are, for example, those of steel corrosion within concrete, problems of freeze-thaw cycles, problems of wood

decay, fatigue of materials, or creep and shrinkage. Since time plays a major role in this case and most of these processes require a relatively long time to cause significant damage to the structure—say over twenty years—the solutions to them are also based on statistical data that cannot accurately determine the lifespan of the structure against these cases. “The problem of steel corrosion has no simple solution” [18], admits Peter Claisse, in his book *Civil Engineering Materials*. But the idea of durability, as Kenneth Frampton points out, is not only tied to space and form but also to place-making and the passage of time, brought to completion through the presence of light, water, wind, and weathering. “Inasmuch as its continuity transcends mortality, building provides the basis for life and culture. In this sense, it is neither high art nor high technology.” [30] The structure is seen as independent of time, as an object that begins with the completion of the works and is supposed to be the same until its expiration date, which is determined in a relationship depending on the parameters of endurance, which can be up to 120 years. It is absurd to think that the structure will remain frozen, independent of anything, during these years. It is transformed by external agents and interacts with living things. To consider time as a dynamic agent means to associate design with constant contradictions. Colonel T. E. Lawrence, observing the ruins of Petra, said that the Romans, trying to build their cities for all time, only managed to remind the next generations of their absurd power, which was temporary and transient like everything in this life. [3] Torroja questions the value of investing in excessive durability. He asks why money should be wasted on longevity when future systems of transport, industrial methods, or living habits cannot be predicted. He points out that many bridges, still structurally sound, have nonetheless been dismantled simply because locomotive weights increased within a few years. For this reason, he argues, the issue demands careful consideration. In some cases, it is reasonable to design with a margin of reserve to accommodate foreseeable increases in load. In others, however, it may be wiser to build nearly provisional structures if they are far less costly and if future functional demands remain uncertain. [3] Meanwhile, Auguste Perret contradicts this idea and considers ruins part of the process and as such, it suggests that they should be thought about as well during design. He writes this paragraph when he criticizes the buildings of the Renaissance era: “Versailles is badly constructed, and when Time will have exerted its mastery over this palace, we shall not be left with a ruin, but with a mass of unidentifiable rubble. This is not Architecture; Architecture is what makes beautiful ruins.” [30]

Contingency in design manifests itself in the design of structure as ornament, not simply as a response to loads. For a structure to be both load-bearing and decorative, it is an ambiguous object—“a both-end” object, as Robert Venturi calls it. Even Torroja, who is a designer of the modern spirit, has an eye for structure as ornament.

The technician and builder have too hard a struggle against environmental nature and society to be denied their privilege of amusing the world occasionally with an incongruous pirouette of mischievous intent. There is profound humanity in the grin of a

clown which gives it perennial justification. The artists of Estella and Barcelona, for example, could appreciate a joke merely because they were artists. Even with those strictly functional elements, the artist knows how to juggle and play with them without contravening their essentially mechanical purpose. He can succeed in altering their aspect, shape, and even their nature in ways entirely unsuspected to the purely technical mind. Thus the ugly tie members that are essential for the stability of a number of slender columns, at the hands of the Cordovean artist became transformed into a wonderful rhythm of open arches surmounted by the vaults of the roofing. (Torroja, 1962) [3]

Furthermore, even though he is keen on structural formalism and rationality, he understands the contingency in structural designing in relation to the aesthetic influence of structures. "...a structure does not depend solely on its mechanical function...", he says, "It can also be derived from other functional qualities and can also be greatly influenced by the construction methods by which it is created." [3] However, an outside observer who is not a professional is usually not able to perceive intuitively what methodology and construction techniques have been used for the structure to be able to evaluate them as values of the structure. Perhaps, for example, a bow-string arch, which is reinforced with braces, may be easier to build than a simple arch. In both cases the structural requirements are met. However, usually the first case is less preferable than the second case, as far as the aesthetic effect is concerned. One of the important tasks of modern designers, as Torroja acknowledges, is to create functionally perfect and attractive structures, within economic possibilities. [3] This relationship between structural and economic efficiency is not at all linear. Interruption of force paths does not mean heavy penalties. On the contrary, a specific framing with right angles can result in a structure with lower cost.

The specifications for the design requirements are one thing and the methods used to achieve those requirements are another. These two aspects are often confused with each other, but in either case, the structure must achieve these specifications. The person who has prepared the specifications does not have to worry about finding ways to implement his requirements. He does not torment himself with the struggles of the structure, when the designers try desperately to fit their project into the other requirements of the building. Even if the structural conditions are met, there are always aspects outside the field of construction, such as the economic aspect, that exert their pressure.

Torroja is also against both purely structural forms and purely economic forms.

There is no merit in saving money by permitting the material to be stressed to its ultimate allowable capacity. The best type of structure is the simplest: one with few main parts of high-bearing capacity, which, in the most direct way possible, conduct the applied forces to the foundations. We should emphasize that the best type does not necessarily mean the cheapest type. (Torroja, 1962) [3]

An example of this case is the design of steel structures, where it is usually practical to replace lighter sections with heavier sections to simplify the construction of the structure, which ultimately results in a cheaper structure. Consequently, he acknowledges that a balance must be found between structural form and economic form in order to achieve a satisfactory structural solution. Construction cost is usually the easiest factor to deal with, and one of the most dominant influences on which designers are evaluated by the clients, whether or not to take the job. However, economic solutions are not necessarily the best solutions, nor are they necessarily the ones that designers will choose. Next, Torroja acknowledges the dependence of structural design on other factors outside the field of structural science: “Money is not the only honorable criterion. There are other factors, difficult to evaluate, which powerfully influence the good designer.” [3] Torroja understands this dependence, but fails to explain the real actors, and gets stuck in the technical aspects of design, as most of engineers in modern times.

As for the influence of the spirit of the time, the following case, taken from the 1958 book *Philosophy of Structures*, clearly reveals the influence of modernism on the writings of structural designers of that time. This text states:

Manual labor must be made simple and economical. Formwork and framework should be reduced whenever possible. Connections should be simplified and reduced to a minimum. The structure will be more satisfactory if its execution is simple, involving no dramatic operations, and if it is adapted to the available means of erection. We should realize that the main supporting structure is an essential part of the total work to be undertaken, and its total economy should be considered as most important. (Torroja, 1962) [3]

Torroja also admits that there are strong reasons to consider during design that may also come from the designer’s desire to make an innovation. This desire may be to introduce a new technology or to increase its knowledge by applying it. However, given so much uncertainty and ambiguity in design values, Torroja urges designers to be careful. In their hearts, there should be no less admissible motives that would compromise their professional integrity. He continues by asking designers to act with a sense of responsibility, and not to interpret mere flaws in design as non-existent major reasons. [3]

Errors that occur during design should be divided into two different levels. The first is the reasons beyond the designer's control, the second is the human reason. As was acknowledged, design is not a 100% safe activity, and errors beyond the designer's power and control can occur. But in many cases, the main reason for a design error comes from the designer's human errors. Consequently, care must be taken because design errors can be camouflaged and claims can be made by designers as if they occurred for reasons beyond their control, masking them as victims of the environment or the social system. Torroja, drawing on his professional experience, observes that error often approaches what was once

called “sin.” Over his long career studying the strength of materials and structures, he examined numerous accidents, many of them fatal, and concluded that very few occur in a morally neutral way. In fact, he found that the vast majority—nine out of ten—are not the result of obscure technical issues but stem from human failings, sometimes bordering on outright negligence or even wickedness. [3]

But if it is taken for granted that designers should not be held responsible for errors outside their jurisdiction and at the same time the profession of structural design is full of outside powers, then the line between what is considered an error and what is considered an accident becomes blurry. Thus, all those unscrupulous designers, whose mistakes have led to the design of low-quality structures and even the loss of human lives, have found refuge in the ambiguous zone of contingency.

Frank Lloyd Wright also feels this problem in the construction profession and calls for integrity as follows:

What is needed most in architecture today is the very thing that is most needed in life—Integrity. Just as it is in a human being, so integrity is the deepest quality in a building...If we succeed, we will have done a great service to our moral nature—the psyche—of our democratic society...Stand up for integrity in your building and you stand for integrity not only in the life of those who did the building but socially a reciprocal relationship is inevitable. (Wright, 1957) [24]

As for professional integrity, Torroja also demands that, when the moment comes, the standards of the past must be questioned. [3] If normality exists for a moment, it is found in the correlation between environment and thought, not in the abstractions of thought. Which means that if we are dealing with a normative, we should at least be allowed to question it at every moment and find solace in a situational approach. Above all, we must be careful not to invert values, which, for example, means not to prioritize economic factors and forget structural performance. This does not mean that we should not consider the economic factor at all and make extremely expensive structures, but not shy away either from making expensive structures, at certain times. We simply must not deceive anyone, especially those who pay us.

Then Torroja demands that designers be understood by society [3], but this contradicts even his previous arguments when he explains that the construction of structures does not necessarily have to be perceived by their observers or treated as a fundamental value. According to his claim, no great art has ever been properly appreciated by uncultured people. [3] But the fact is that urban art is not confined within the walls of a museum. Buildings reflect their authority on all of us and, consequently, the messages they convey still affect the majority, whether they are scholars or ordinary people. Once the construction contract is signed, the structure becomes independent of the role of the designer. Colin Rowe reminds

us that, although architects in modernism built without a theory of architecture by denying the values of form, still their buildings exhibit certain values since they possess the authenticity of time. [31] Therefore the claim that society must achieve a certain emancipation to appreciate better the values of the profession of the structural designer is unsound.

The opposite, however, seems more feasible. Torroja once again reveals his contradictory stance, admitting that while efficiency and meeting material needs are important, those needs are often more flexible than assumed. He stresses that people also have subjective needs, which, if ignored, may provoke serious social unrest. “So, when I listen to some of my engineering colleagues talking, I sometimes shake in my shoes”, [3] he confesses, because many treat the aesthetic consequences of their work as trivial or even frivolous. For him, the danger is that as material prosperity grows, the long-term catastrophe will be greater if people are deprived of aesthetic fulfillment. [3]

It is this connection between form and our consciousness that makes structural design inseparable from social aspects. Juhani Pallasmaa says: “The architecture of Michelangelo does not present symbols of melancholy; his buildings actually mourn. When experiencing a work of art, a curious exchange takes place; the work projects its aura, and we project our own emotions and perceptions on the work.” [24] The melancholy in Michelangelo’s structures is entirely from the observer’s personal experience, initiated by the authority of the work. We become part of the work. Our consciousness takes us to images of the city of another, much older time. The rooms, streets and squares are transformed and our imagination experiences life in Ancient Rome. This happens every time we encounter a structure. “We become citizens of mid-19th-century St Petersburg through the incantations of Dostoyevsky... We are in the room of Raskolnikov’s shocking double murder, we are among the terrified spectators watching Mikolka and his drunken friends beat a horse to death, frustrated by our inability to prevent the insane and purposeless cruelty.” [24], says Pallasmaa.

As for the structure, it is not the same as its drawing, just as the drawing is not the same as its report. The delusion that a drawing is the equivalent of construction can only be accepted if one sees the structural design as separated from contingent reality. “...in city planning ‘medical’ solutions are a delusion; they resolve nothing, they are very expensive. Surgical solutions resolve.” [32], says Corbusier. According to him, we must put an end to the disease and remove the cancerous elements and only then can we begin the path to orderly perfection. Once again we are presented with the triangle of cleanliness, purity, and the rules that eliminate or exclude all rogue objects. Zygmunt Bauman explains this point: “Orderly space is rule-governed space... the rule is a rule in as far as it forbids and excludes.” [33] My suspicion is that structural theories, including those that discuss philosophical approaches to structures, have ignored contingency because it is much more real than anyone can control.

It constantly reminds us of our fragility, our bodies, politics, etc. It especially reminds us of others and the responsibilities we have towards them. In the field of sociology there is no place for autonomy. Therefore, the whole idea of structural design as an independent discipline will be treated with the disdain it deserves. Structural design can never control the actions of users, nor the events of the structure. In the science of Structural Design, if we consider it as engineers like to think, values are transformed into computational objectives and computational objectives into functions and thus, it becomes very easy to manage them. In this transformation, it is assumed that nothing is lost. But computational objectives are very different from structural values. This difference between them is one of the many links that contribute to the mismatch between structural design as they want it to be and what it really is.

The metaphor of structural design as an independent field is so powerful that it makes people believe that it is also the reality of structures. From the mass of people involved, the danger comes when structural designers themselves believe this. As a result, structural design as metaphor dominates structures themselves. Jeremy Till admits that the will to order in architecture is ultimately metaphorical rather than literal. As he cautions, “We have already seen what happens when one starts to confuse the metaphorical for the real: the deluded belief that architecture can be autonomous”, [8] a stance that produces self-referentiality and suppresses contingency. [8]

Structural design, and even architectural design, are exposed to contingency, and this ambiguous mass does not fit into any of the ideal schemes of modern activity. We saw above, however, that not only is structural design contingent as a profession, but also the process, product, and activity of structures are contingent. Of course, one could say that all life processes are interconnected and the things I am saying are self-explanatory. However, structural design as an activity is particularly exposed to external factors and if we are to find value in it we must accept that it is contingent. A building designer—a structural designer or an architect, for example—does not have the luxury of being alone, nor the precision of standard methods, nor the conformity of a non-contradictory flow of the values of the profession. Even a simple sketch may seem innocent at first glance, but it is conditioned by previous experiences and current expectations. Then the whole process falls under the control of others—clients, other designers, engineers, consultants, potential users of the building, regulators, etc. Structural designers can indeed try to relax all this flux by imposing standard design methodologies, but the hurricane that comes from outside never goes away. Once the project is handed over to the contractor, the construction industry leaves its mark with its own mass of uncertainties. Then when the building is handed over to the client, another series of even more unpredictable actions require participation: users leave, others come, time and atmospheric agents take their course, new technologies as well, events, criticisms, etc. Structures never get comfortable, and neither does structural design.

Regarding the tendency of structural design to hide within the territory of science, Giddens observes that public attitudes toward science and technical expertise are marked by ambivalence. He argues that trust becomes necessary precisely where knowledge is lacking, but such ignorance also leaves room for doubt and cautious reserve. [34] The result, as he argues, is that people bargain with the modern spirit, in terms of the trust they invest in “symbolic tokens” and the human need to seek expertise and certainty. However, this whole bargaining process is accompanied by a mix of deference and suspicion, comfort and fear.

When I leave the site visit to the Green Coast complex in Palasë (fig.33), a debate begins. I hold a vision of a dystopian presence of authority, while the engineers who work there justify how the buildings have achieved environmental certifications and advanced design techniques. This is the problem. Their arguments come across as logical, how the building is almost a perfection of form and technique, while my point of view is treated as pure emotion. They win, because in the modern world, regarding structural design, it is accepted that logic always triumphs over emotions.



Figure 32 - A green coast, Palasë, (author, 2014)



Figure 33 - Green Coast Resort, Palasë, (author, 2025)

Construction and demolition are closer than most designers claim. In order to preserve the dignity of the metaphor of structural design, it is necessary to separate construction from demolition. Only in this way would the profession distance itself from any connotation of wreckage. This is literally what happens on the construction site. Demolition contracts are often independent from the main contracts, and a different subcontractor is always assigned to it. Structural designers do not deal with demolition contractors because to control this

activity means to embrace disorder. As designers, we like to come to a clean site, to start everything from the foundations. In this way we can “exorcize” all the demolition mess that always follows the construction process. This mess comes from economic, social, political factors, which are directed by people from the same “dark world”. “Where there is design, there is waste”, [33] admits Bauman. The production of the new, whether in the case of buildings or other amenities, always has a shadow that comes with the production of waste. The point here is not to accept waste as a design value, but in fact I want to highlight two problems. The first is that waste disrupts the classical system of values in design, and the second is to show the importance of time in design. Waste confronts us with the potential and the inevitable process of time. Photographs enable us to forget what came before it (the chaos of the construction site and the desperation of the workers to complete the project on time), as well as what will come after it (the confrontation of buildings with time that defiles, changes, destroys structures). Photography freezes time, or rather, photography freezes outside of time. Mass production of visual images, such as photography, tends to turn the image into a mesmerizing flow without focus and without the possibility of participation. Michel de Certeau raises this concern when he says: “From television to newspapers, from advertising to all sorts of mercantile epiphanies, our society is characterized by a cancerous growth of vision, measuring everything by its ability to show or be shown.” [24] He adds that this tendency transforms communication into a purely visual journey, a dynamic reflected in the proliferation of shallow architectural imagery today—imagery stripped of tectonic coherence, material grounding, and empathy. [24]

Pallasmaa also speaks about the dominance of static appearance and the reduction of values because of vision’s dominance:

The gradually growing hegemony of the eye seems to be parallel with the development of Western ego-consciousness and the gradually increasing separation of the self and the world; vision separates us from the world whereas the other senses unite us with it. Artistic expression is engaged with pre-verbal meanings of the world, meanings that are incorporated and lived rather than simply intellectually understood. In my view, poetry has the capacity of bringing us momentarily back to the oral and enveloping world. The re-oralized word of poetry brings us back to the center of an interior world. (Pallasmaa, 1996) [24]

Not a few designers have denounced the hegemony of the eye over the other senses. Even Torroja says: “Let us not forget that the beauty of structural design work is known through sight. This is perhaps the most deceptive of the five senses with which we are endowed.” [3]

Indeed, the eye claims dominance over all areas of cultural production, and, in Pallasmaa's words, “seems to weaken our capacity for empathy, compassion and participation with the world.” [24] The narcissistic sense of sight sees structure only as an expressive feature of

itself, as an artistic play deprived of social and mental connections. Instead of reinforcing the body's experience of the world, nihilistic images put up a wall with the world and isolate the body, and instead of restoring cultural order, they make it impossible to read the distorted collective meanings. As a result, the world becomes a meaningless visual journey. All this state of affairs, according to Pallasmaa, has come from the increasing dominance of the sense of sight in the new culture, since it is the only sense among all the others capable of perceiving at a distance and independently of objects. [24] To make a comparison, it is impossible to think that the sense of touch or even that of smell carries the same negative impact on distancing man from the world around him, knowing they are active at a relatively short distance. Instead of being a situational body encounter, buildings have become fixed images in the direction of the focus of the distracted eye. In the culture of images, the gaze flattens the world into a picture and objects lose their plasticity. Instead of experiencing ourselves situated in the place, we take on the role of spectator and see only the projection of the world on the retina of our eyes.

The photograph of the newly completed building creates the illusion for the structural designer that he has finally achieved a sustainable product. Time is accepted in structural design only in its linear form and as a statistical value, which strips time of its ambiguous nature. But this is an impossible mission. The interaction between time with all its full power and the structure will happen anyway. In addition to the photograph, which has become the main tool for identifying the success of the project by the designer, the second most important moment are the renders that go to the client and fill his eye with images until he sets the new terms of design. Freezing time before and after this meeting deprives the design of the possibility of receiving real inputs from the client and other potential users. Another form of time that is not taken into account in design is time's human dimension, which includes memories, expectations, histories, the potential for the future, etc. Of course, all these forms of time act on structural design, but designers distance themselves from them because of their inability to control them. But with its influence, time introduces a diversity of forces that structural design must acknowledge—time as event, linear, cyclical, individual, etc. To acknowledge this, Jeremy Till suggests that “[design] has to relinquish its mythology of stability and strength.” [8]

During my mobility period in Spain, I decided to visit Eduardo Torroja's Zarzuela Hippodrome. It is a project that I had wanted to see since I was a student, especially to see up close the bold and visionary shell structure that covers the stadium's seating areas. Upon arriving at the site, however, I was disappointed. The hall is surrounded by uncoordinated extensions and additional service structures, which obscure the view of the stadium's roof. Part of the stadium was closed to visitors because it was undergoing restoration and had been like that for many years.



Figure 34 - Zarzuela Hippodrome (author, 2025)

The rest was not closed, but there were horse races only on weekends and you couldn't enter the stadium without a ticket and without seeing a race. The scaffolding was the structure that dominated the view. As soon as I entered the lobby, however, I was confronted with a part of the shell structure and I was able to perceive the brilliant vision of the author. For a moment I imagined that place full, with the regular stadium without scaffolding, without the steel structures. Torroja's vision was to create a structure that was elegant and orderly at the same time. Like a feather that lightly touched the sky and was allowed to stay there long enough to shade the people below who were enthusiastically cheering for their champions. Today, almost a century after the design, much of that intended clarity has been diluted by patches and clutter. It was 40 degrees that day. I couldn't go sit under the shell structure, I could only see a part of it behind the scaffolding, in the heat (fig.34).

With the increase in specialization in the field of construction, the neglect of contingency also increases. An example of this case are the cost estimators, who are professionals in Albania who deal with construction cost estimates, and are usually engineers or architects. There are many countries in the world where this profession does not exist, but in Albania it is a stabilized profession, with its own defined norms and methodologies. One of the report required for this activity is the Bill of Quantities, which are several Excel sheets that reduce the entire design project to units and quantities of work. It was one of the first documents that I did as an engineer, while working for the design of an oil factory, in 2020. We had carefully drawn all the project sheets and sent them to the team leader by email to delegate to the supervisor for approval. The team leader calls us on the phone and asks: "Where is the Bill of Quantities? I can't send it without having one." "But we have never done a Bill of Quantities. We only do the project drawings", I told him. And really, I didn't know how to do them. I had never done them before. I was very good at drawing in CAD the details of

beams and other elements and completing a structural project accurately and quickly according to the team leader's directives, but for me the project ended there. For the surveyor, the person in charge who had asked our team leader for the measure book, the project existed only as a Bill of Quantities and as a Preventive. We had to complete it all within two days and then it took us a month to go back and correct it. In overall, it was an interesting project, actually, because there were many reinforced concrete wall elements at different levels, but this made the experience of drafting the Bill of Quantities even more difficult. However, years later I became curious and checked how the project was implemented and discovered that its construction never actually started and a hotel had been built on the same site.

The absurdity of the specialization of the structural designer profession, which is increasingly moving away from the real work—that of designing structures—may also be related to structural formalism. Peter Eisenman argues that when form is no longer grounded in factors such as function, program, meaning, technology, or client demands, the only remaining justification becomes the rationality of the design process itself and the internal logic of form. [35] What he is saying is that the problems of use, values, and clients are very different from one another and cannot all be collected within a single regulator and as a result designers come up with more rational parameters to describe the design process. This allows them to satisfy at least the constraints necessary to make structures possible. It makes them comfortable, at least with the left side² of the brain that deals with logic and analysis. But the other aspect of design that is covered by the right side of the brain and overlaps with rational parameters, is the one that contains the values of structural design. The uncanny thing about structural design creativity is that it resists a proper and complete explanation. It is precisely this enigmatic quality that gives design its value and distances it from the tasks that can be performed entirely by machines and computers.

Rational constraints should not be absolutely discarded. Even classical methods of solving forms are acceptable as long as they are in the service of something outside their standard self-referential realms. In fact, what I am asking is that at the core of the ethics of structural design should be the idea that this activity is a service to people. One of the frequent mistakes made is to assume that professional conduct has ethical values. It is like saying that if you rigorously follow the design code, you will ensure ethical behavior.

When many buildings were destroyed during the 2019 earthquake in Albania, an explanation I kept hearing in those days from structural designers was that the destruction came from soft-stories. But this framing, although technically convincing, did nothing more than cover up the real reasons for the destruction. Developers cut costs, contractors worked shoddily, the project was never entirely completed, and residents made building changes and

² The common belief that people are either “left-brained” or “right-brained” is a myth. In reality, both sides of the brain are constantly working together. The use here is symbolic.

constantly damaged the structures. The structure of the building that caused the highest number of deaths during that event had ended its life cycle way before and had been identified by professionals as uninhabitable and residents had been warned to be careful in case of earthquakes. The question that few asked before the earthquake occurred was: “Where would these residents go?” The structure in which they slept every day had become a potential coffin for them, and they bargained their present lives with their future lives. Poverty, politics, culture, education, awareness, and many other social factors. Meanwhile, the structural designers, those who were supposed to understand the causes of destruction better than others and those who had the responsibility of speaking out for such a critical case, said in unison: “Soft-stories”. The reason structural designers fail to address the main actors that cause damage is that they always tend to find problems within the jurisdiction of their field. To do so would be to control the problems and thus to be the only ones who can seemingly provide solutions. But phenomena do not happen that way. They are ambiguous, situational, and outside the scope of anyone’s expertise. Recognizing this is the first step toward better design. This is not to say that structures should be built without considering the usual rules of design. However, to claim that the problems of structures arise because of their geometry is not simply naive, it is a deliberate agenda to keep structural design within a territory where simple solutions can only be provided by specializing and deepening, not by extending. This claim is just an open invitation to increase profits from the construction market and to make a wanted product on the market.

By accepting contingency, we return once more to our human world. The normal, the one accepted by the profession, should not be opposed to the pathological—the one removed from the profession—because, as Georges Canguilhem says, in certain conditions, in its own way, even the pathological is normal. Healthy structural design—the one that is stable and esteemed—is much more than normality. In simple terms, it is the only norm that is indisputable. Then, for every other case of norms, Canguilhem encourages us to put them all to the test. He urges us to scrutinize apparent normality, asking whether it can withstand infractions, resolve contradictions, and adapt to conflict. He argues that true normativity—or health—lies in normality open to future correction and variation. In contrast, a state of normality that seeks only to preserve itself, resists change, and cannot respond to new conditions, lacks genuine normative intent. Thus, whenever faced with what seems normal, we must ask whether its norms are creative and future-oriented or conservative, pushing back toward the past. [36]

Canguilhem argues that in biology the “normal” does not necessarily mean the old but rather the new form—provided it finds conditions that allow it to establish itself as normative, displacing outdated or declining forms. He adds that no phenomenon labeled normal can claim the authority of the norm itself once the conditions that supported its normative status have disappeared. [36] What defines normal and pathological in nature is the situation in which they both find themselves, and decides whether or not they will survive in the future.

He argues that no fact is inherently normal or pathological. An anomaly or mutation, in itself, does not constitute pathology but rather represents an alternative possible norm of life. If this new norm proves weaker than earlier ones in terms of stability, fertility, or adaptability, it is labeled pathological. If it proves equal in the same environment, or even superior in a different one, it is regarded as normal. In this sense, normality arises from normativity. Pathology, therefore, is not the absence of a biological norm but another norm that life, by comparison, has relegated to the margins. [36]

In a similar way, no contingency is a danger, and should not be pushed aside. On the contrary, it should be seen as an opportunity. We must always weigh up the effects of the contingency on the normal projection and create norms that reflect the values of the time.

Canguilhem insists that “No environment is normal. An environment is as it may be. No structure is normal in itself. It is the relationship between the environment and the living thing that determines what is normal in both.” [36] He explains that a living being is truly normal when life sustains itself within forms and norms that allow flexibility, permitting variation so that as conditions change, some forms may prove more viable. An environment is normal when it enables a species to thrive, diversify, and adapt to modifications without threatening survival. Conversely, when either life or environment cannot accommodate change, the condition becomes pathological, for illness is precisely the incapacity to tolerate change. [36]

In the case of structural design, the environment are actually societies. It is clear that no societies throughout history have been perfect either. However, they dictate to the design requirements that the design must achieve, otherwise it is destined to fail and disappear as an activity. As for the scientific values of design, there must be some solid scientific rules that will pass all the filters of the requirements of societies, without which structural design cannot exist. However, Canguilhem challenges this assumption, noting that “certainly this environment, which science defines, is made of laws, but these laws are theoretical abstractions.” [36] He argues that living beings exist not in the realm of abstract laws but in relation to other creatures and events that constantly modify those laws. For example, what supports a bird is the branch itself, not the principle of elasticity. If the branch is reduced to elasticity alone, then the bird becomes nothing more than colloidal solutions. At such an abstract level, the notions of environment, health, or disease dissolve, leaving only processes of becoming and history. [36]

I am saying it once again. I will not profess indeterminism, an approach often supported today. What I want to propose is that solutions to structures must be situational and based on human experience, not just science. Science can partially explain experience, but it in no way cancels it. Experienced life falls short of its challenges, but when necessary, it can surpass pre-determined expectations.

2.4 Embracing Contingency

We must face danger calmly; having previously accepted all its consequences, provided there is justification in the risk. Then we shall feel pride in our responsibility, for our conscience will assure us that higher motives and potential advantages justify such dangers. It is precisely this, and only this, that gives true merit to, and enhances, our creative mission. (Torroja, 1962) [3]

Of all the difficult tasks that modern civilisation sought to do, the most difficult was the task of order, or more precisely the establishment of rules for tasks. The struggle for order is not a battle of one definition over another definition, of one way to articulate reality against another competing proposal. It is a battle of determinism against ambiguity, of precision against ambivalence, of transparency against turbulence, of clarity against confusion. The alternative to order is not another order. It is in fact chaos. [8] The alternative to order is a set of states of indeterminacy and unpredictability. Here comes uncertainty, which is the origin of all fears. The gardener pulls out the wild plants because he wants to have control over the nature in his garden. As we saw above with structural design, as with all modern age projects, the more one tries to eliminate the Other of order, the faster it comes back to haunt one. The wild plants always return. The whiter the wall, the easier it gets dirty.

The impulse of creativity that comes out of nowhere is incalculable, frightening. Instead, control and comfort are preferred. Therefore, during the design, rigid limits are set, and the initial idea is broken down into more digestible parts. Then we seek to include isolated repeating motifs as part of the creative process, as if this would reflect irreducible units of continuity. We want to believe that there are things that are the same forever. But as Balmond says: “It is hard to believe in singularities, to gaps or folds in the thinking, as random start points create fault planes in the belief of homogeneity.” [19] In the face of all this turbulence, order is preferred as a secure fortress. However, it misses the point. Reality is contingent, and order can only be a small and local state of a set of random states. Creative ideas do not follow the principles of a rigid hierarchy, but come from the intensive exploration of the intermediate.

Tadao Ando has found his own solution to this issue by first addressing functional requirements and then exploring how architecture can extend beyond them. For him, the essence of architecture is defined by the degree of separation it achieves from pure function. [24]

According to Bauman, contingency and order always arise together: “Awareness of the world’s contingency and the idea of order as the goal and result of the practice of ordering were born together, like twins; perhaps even Siamese twins.” [37] The reason is simple. We would not be so determined to establish order if we did not experience disorder. He continues

by explaining that the very notion of order arises only when we are confronted with the unexpected and with contingency. As he puts it, “if one wants things and events to be regular, repeatable, and predictable, one must do something about it; they won’t be such on their own.” [37] What the modern spirit does is separate these twins at birth and keep one away in order for the other to have the privilege of living unbothered. According to it, contingency must be suppressed so as not to weaken the authority of the logical. Hegel and Bauman are among the philosophers who oppose this action. For Hegel, reality cannot be self-sufficient as long as it does not contain the irrationality that does characterize it. [38] Consequently, contingency must be allowed to surface. Bauman also states: “[we] must transfer contingency from the vocabulary of dashed hopes into that of the opportunity, from the language of domination into that of emancipation.” [39]

Jeremy Till also has the same point of view:

What if instead one follows the line of the Buddhist thinker Sogyal Rinpoche? “The constant uncertainty may make everything seem bleak and almost hopeless,” he writes, “but if you look more deeply at it, you will see that its very nature creates gaps, spaces in which profound chance and opportunities for transformation are continuously flowering—if, that is, they can be seen and seized.” Where order and certainty close things down into fixed ways of doing things, contingency and uncertainty open up liberating possibilities for action. In this light contingency is more than just fate; it is truly an opportunity. (Till, 2009) [8]

Even Louis Althusser has the same opinion: “...instead of thinking of contingency as a modality of or an exception to the necessary, one must think of necessity as the becoming-necessary of contingent encounters.” [40]

What will happen if we listen to Ando, Balmond, Till, Bauman and many others who demand that we must bridge the gap by allowing dependency not as a danger but as an opportunity? That the inevitable reality is accepted in its full form. And that in this connection there is the potential for a reformation of the practice of structural design that will withstand the new age of computers and will give hope and represent the values of the time. What then?

Contingency requires us to make choices. These choices are not easy at all because they do not have a manual and they determine the path in front of us. As Alberto Melucci says: “The imperative that immediately arises from uncertainty is therefore the necessity to choose...it is impossible not to choose among the options available in any situation.” [41] I want to clarify here that these choices should not be random; on the contrary, each of them carries a weight that must be well evaluated. Therefore, the nature of these choices is very far from being relativistic and very far from being so deterministic that there is no need for them to be weighed. As long as we undertake to make these choices with some kind of vision and purpose, there will be hope for the good conclusion of this process. Meanwhile, in

modernism, the end of the process is preceded by predetermined values, and consequently, the path to design is almost mechanical. In contingent reality, the true end is uncertain, and the choices made in the process of getting there are exposed to other agents, and in particular to the goals and desires of others. Contingency, then, requires us to share our fates with others. This does not mean that we must agree with the clients and people we will deal with during the design process. It simply means accepting their influence and being less dogmatic and listening more. Dealing with contingency means having a vision but at the same time being modest and open-minded enough to allow this vision to be affected by other circumstances. Another reason why these choices should not be made randomly, nor predetermined, is that when we are faced with this act we are sentient, situated people with a certain level of knowledge. We weigh these choices with a concrete background, which allows us to measure, but in no way to determine them precisely. This act differs greatly from the modernist spirit that dictates that choices be made based on an infallible manual determined by an authority at a higher level than ourselves. Individuals in the modern era are liberated from the act of making important decisions because they are answered by a superhuman system that covers all issues regarding that context. The acceptance of contingent reality, on the other hand, rejects this delusion of knowledge located somewhere in an all-powerful manual, and brings these issues down to earth, and requires a solution from man. Haraway makes a suggestion for this problem. She asks us to immediately reject the concept of objectivity. By doing this, we lose our comfort because we will be within the Other of objectivity which is subjectivity and we must take personal responsibility for our choices. To find a light that will help us in these situations, she proposes situated knowledge. Situated knowledge deals with the particular. She implies: “the only way to find a larger vision is to be somewhere in particular.” [42] To see problems case-by-case, taking an optimistic approach, but this optimism is still case-by-case, not perfect. Situated knowledge implies partial knowledge of the problem, not complete knowledge. Nevertheless, this, coupled with its modest and honest nature, is seen as an advantage, not a disadvantage. It does not assume that it has a universal authority on the problems of that field, but this does not mean that it is irrelevant. The way it works is that it uses information from the past to build a better, but not ideal future.

Regarding the potential of contingency, John Dewey suggests that freedom depends on contingency, though contingency alone cannot secure it. In a world of total determinacy, freedom would be impossible; contingency merely creates the possibility of freedom without guaranteeing its realization. [43] Although contingency gives you more freedom, it is not sufficient to provide solutions. With this in mind, I do not propose contingency as the only condition that will provide us with solutions to the problems of structural design. What I am suggesting is that contingency is in fact an important quality of design that should be taken into account rather than dismissed as a threat to design. This contingency is what places us in a real-life event, giving us the opportunity to develop and transform, knowing that

perfection does not exist. That is to say, when I suggested Time as one of the main aspects that act on structures, this does not mean that we should abstract Time further and fill our methodologies with predictions to take into account its effects. On the contrary, I want to think about the space filled with Time during the design, and not freeze it, as the project of modernism did for structures, which we will discuss it in the next chapter. Lefebvre attacks precisely this aspect of modernism when he says: “with the advent of modernity, time has vanished from social space.” [44] Therefore, we need to find ways to re-present it. If we consider the full Time, with all its characteristics, as one of the main factors that act on structures, then they are revived, become dynamic, social and freed from the stigma of static. “We must acknowledge that in reality buildings have to be understood in terms of several different timescales over which they change, in terms of moving images and ideas in flux.” [45], says Steven Groák. To bring time back into design, you have to start with what you know and what you see and experience. Embrace the everyday, look at projects all around. Put aside the clock because it does not show the full time, it only shows the linear one. Embrace cyclical time, instantaneous time (earthquakes for example), time as memory, rituals, etc. The best way to find time is to experience it. You will find it in novels and poetry. Alternatively, you will find it in history books. Or you will find personal time, discussing a story with family, and so on. Lefebvre also mentions “‘The everyday’ is situated at the intersection of two modes of repetition: the cyclical, which dominates in nature, and the linear, which dominates in processes known as ‘rational’.” [46] Everyday life is characterized by constant repetition and cyclical events, but it is also open to unexpected and chance events. Everyday life is the result of practices that are repeated and as a result have traces of the past, but thanks to its imperfection, there is also the possibility of being reformulated and changed continuously. In other words, according to Lefebvre: “the riddle of recurrence intercepts the theory of becoming.” [47] Therefore, everyday time represents the full Time with all its characteristics. In the context of structural design, techniques, theories, structures, methods, past experience are projected into everyday time with hopes, dreams, desires, ambitions, and possibilities of the future. Past experience alone is not enough for design, as this means that we are condemned to repeat the same things over and over. Hope alone is not enough either, because, as we will see in the next chapter, civilizations that erase the past with the hope of a barrier-free future and dream of a perfect world are prone to failure. By mixing past experience with the hope of the future, the full Time comes into structural design as lived time. Structural designers instinctively resist this vernacular, as it threatens their very existence, because it is beyond their control.

Another solution suggested by David Leatherbarrow and Mohsen Mostafavi, to accept contingency and full time in design, is to see buildings as unfinished even when they are finished. [48]

An extreme example of this is the facade of Sagrada Família (fig.35 and fig.36).

There we have unfolded the action of about 150 years of full Time. It is enough to see how one part has been transformed and how other, newer parts do not yet have that aura that the interaction of time offers.

It is contradictory to see how one part is being built and other parts are being restored because they have passed their life cycle.

All this within a structure. Nevertheless, all structures are in constant change and in an on-going transformation.

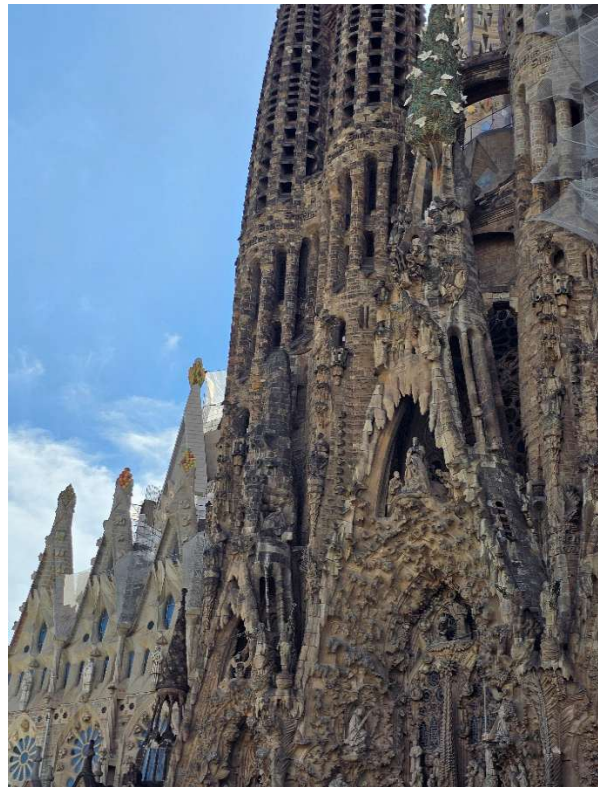


Figure 35 - Sagrada Família, the old facade (author, 2025)

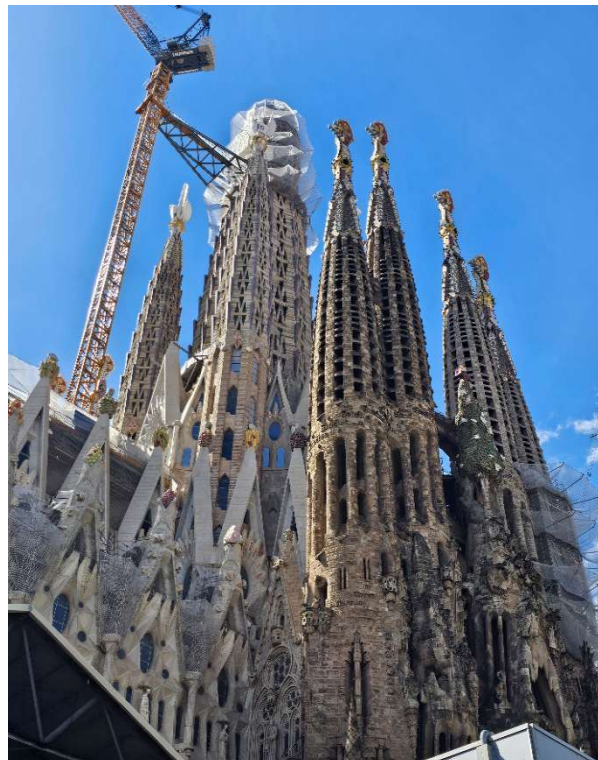


Figure 36 - Sagrada Família; the old facade, the new facade, the "yet" to be build facade, and the facade in restoration (author, 2025)

One of the aspects of the modern era is that, in the search for clarity and unconditional ideals, these ideals could stop the processes of entropy. Buckminster Fuller even sought to solve the problem of entropy once and for all by inventing a new term, that of syntropy, which according to him is the tendency of reality to move towards order. The invention of concepts for problems and their solution are so far apart that only someone drowned inside the spirit of modernism could confuse them. Indeed, structural design is immersed in uncontrollable forces. Time is one of them. As we have already seen, forces coming from social aspects also influence design, such as the economy, users and clients, the changing functions of the building. But all this entropy embraced during design does not reduce the possibility of cooperation with these forces. In fact, it strengthens it. Structural designers only deal with what others and time have started and will continue later. However, accepting this means changing the concept of structural design to not rely on certain moments that in design are considered the completion of our work. Such is, for example, the 28-day deadline for concrete, or the deadline for completion of construction based on the Construction Schedule. Instead, Till also suggests that we consider our work as incomplete. [8] Lars Lerup too suggests “building the unfinished”. [49]

Jeremy Till describes building his house as an exercise in embracing contingency within architecture. For him, design begins with exchanging stories with the future inhabitants: “We [Jeremy and his wife, Sarah] tell stories of our memories, we project stories of our future; stories that fill the soon-to-be house with time.” [8] Because these stories are flexible and open to negotiation, the design evolved gradually and collaboratively. By the time the first sketch appeared—drawn by Sarah on a scrap of paper during a conference—it already embodied their shared narratives, shaping a structure in which both felt at home. [8]

Then, he and his wife redrew their sketches so often they seemed to acquire a life of their own. “These drawings trace the course of a dinner party from the perfect order of the initial place setting...to a plan of the table at the end of the meal, laden with the detritus of plates, food, and drink.” This final drawing, he says, became a metaphor for the house: a set of objects that appeared disordered but in fact allowed everyday life and time to pass through freely. Still, the looseness of the house—its ability, as one critic observed, to “accept the vicissitudes of everyday life”—came less from the drawings themselves than from the stories behind them. [8]

The whole purpose of this journey is to free architecture from the clutches of abstract thought and allow it to be created by the contingent forces of time flow and social flow. The process of doing things for Till is what actually provides the opportunity to design well. Therefore, when Till thinks about design, he does not think about activities but about the processes of doing them. For example, he does not think about the plan, but about planning. Similarly, he does not think about the building, but about building, etc. This process is open to benefit from the contribution of other forces, including clients, builders, architects, users, etc.

Another example of building design, embracing contingency, comes from Alvar Aalto. His architecture is based on sensorial realism. His buildings are not based on any pre-established dominant concept or principle. Instead, Aalto chooses to design according to sensory agglomerations. Because he operates in this way, his projects sometimes seem clumsy and unfinished, but they are in fact designed to provide livable physical spaces, not constructions of a dogmatic vision. [24]

Another way of designing that embraces contingency comes again from Jeremy Till, when he suggests “Lo-fi architecture”. [8] By this concept, he means that the designer should design using all his best skills and, at the same time, be very aware of the events that his project may face.

Unfortunately, today's culture is dominated by buildings that have no connection to everyday life. Tirana and the Albanian coast are a valuable diary of truths, as far as this issue is concerned. Large resorts, which are not inhabited. Luxury villas on the coast used only two months a year. Entire old empty apartments left to the mercy of fate. On the other hand, endless new constructions left unfinished, with naked structures perfectly suited for lifelessness.

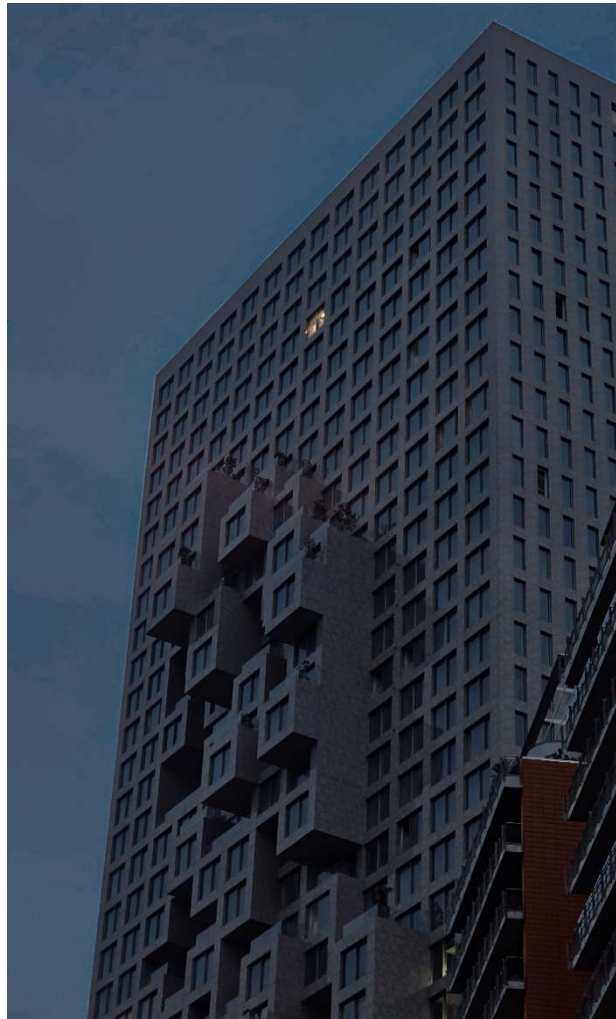


Figure 37 – A high building with no lights on, Tiranë (author, 2025)

In short, a building that ignores the everyday will be ignored every day. This does not mean that we should be overwhelmed by the everyday and repeat the buildings we find around us. This is not neither an invitation to embrace popular motifs and make populist buildings in the hope that we will meet the demands and expectations of the people. What Till and Lefebvre suggest is that we accept the ordinary, get used to it and, in certain cases, why not, consider it as a design value. [8] There is a tendency in universities for students to seek to make abnormal projects, thinking that this will increase the values of their project. Then, out of the great desire to do unusual things, they surrender the usual values of design, for

example, they forget to create themselves, and leave the creative process to an AI. This whole movement, first to demand more from reality and then to lose touch with the values of reality, represents today the failure of the avant-garde.

The more typologies, design manuals, schedules, and specifications are divided into categories and systems in order to control structural design; the more it will be numbed by them. If you think that structural designers are in control of structural design, it is enough to look at traditional buildings and ask you “Are we making progress in terms of the values of structures?” While professional knowledge preaches about the efficiency of the methods used to build structures, what is actually needed in practice are ways of thinking to deal with unexpected situations. Again, the division that shows the separation of the profession from what we think we do to what practice requires us to do. It is precisely after practical experience that designers understand that they need to listen more, to collaborate more, to know how to communicate. This model of the structural designer as an interpretive agent is a consequence of the values of the spirit of the times and requires professionals to come down from the pedestal to which they have placed themselves and interact with others.

Jeremy Till also suggests that we consider professional knowledge as part of a network that connects the human with the non-human, specialized knowledge with everyday knowledge, rules with instincts, and social sciences with social life. [8] As Lefebvre says: “superior, differentiated and highly specialized activities have never been separate from everyday practice, [but] have only appeared to be so.” [50] What is required of structural designers is to face their fears and the fact that they are normal. Their fear is that, if they admit that they are like everyone else, they will lose the mantle of the professional authority, and they will no longer have any power to provide solutions. However, what modern man does not understand is that instinct and everyday insights are not random impulses. In fact, they are obtained within the context of professional experience, which in our case is developed by being a professional in structural design. A chess grandmaster, for example, contrary to the myth that is thought to memorize 100 moves in advance and then act, in fact sees only one move, the right one. However, since structural design is a social activity, unlike the game of chess, these insights are offered as interconnected with other requirements that are not related to professional knowledge. All of this reinforces the argument that knowledge about structural design should not be applied as abstractions outside the context of the project being carried out. It may happen that you may design several similar projects. Also, of course, you can take as a reference some other projects for your work. However, you should always be careful to question previous experiences and always be inclined to be open to changes depending on the case. This activity requires a different kind of knowledge. The profession of structural designer has traditionally preached the know-how and know-that approach. Which means that structural designers apply their knowledge either in the form of theoretical principles and facts (know-that) or in the form of technical skills (know-how). Instead of this knowledge, John Shotter suggests that we learn “know-from-within”, which is

developmental knowledge that adapts and grows from the socio-cultural environment in which we are. [51]

Another way of embracing contingency during structural design is through participatory design. It has been shown by practice that some kind of participation is always better than no participation, as people tend to connect with the design if they have worked with it from the get-going. Henry Sanoff also states: “Participation generates a sense of ownership; people are more likely to protect, support, and maintain environments they have helped to create.” [52] However, the methods used for participation are romantically idealistic. They require 50/50 cooperation from all parties, and this never happens. Instead, why not embrace what actually happens in a meeting: to negotiate. This is a more realistic approach and in reality, it is what actually happens. Never forget that contingency works for every part of structural design, and this also includes participation. It is never 50/50. You can never hope that simply being open to the ideas of others will produce a better project. At best, it will produce a muddle design, at worst it will unashamedly fill clients’ needs for spaces and will disregard all the others that are not in the table, including you and your design values.

Modern design has given us the dogma that the form of a structure must have unity. Robert Venturi refutes this claim by stating that complexity and the opposite of unity are vital and represent life. [53] As a final attempt by modernists to cover the denied contingency that was becoming apparent in modern design, Buckminster Fuller created the concept of synergy, which states that, however inexplicable something may be, it can influence the Whole. [54] Not only that, but according to Buckminster Fuller, the Whole—the Unity—had two sides, the explainable and the yet-inexplicable. Thus, he explained that the reason why the transformation of completely clear processes into other completely clear processes had unexplainable losses was precisely that man was not able yet to decipher the other part of this connection that influenced the transformation process. [54] What modernists refuse to accept is that all activities are and will always be contingent, especially those that are closely related to daily social life and are under the continuous action of time. It is clear that no one has any idea how life works and that no one has control over their lives. Nevertheless, we have a set of rules and values that we define ourselves, which are, of course, influenced by society. They are necessary because, without them, we would not find motive to get out of bed. Which means that in design there is a first moment when the designer places himself before the unclear and the unknown, and then, a second moment when he hopefully makes better rules thanks to the reflection and choices he makes in the first moment.

Another solution—if I can call it that—is precisely the rejection of the problem solving approach in structural design. Problem solving is the way the profession legitimizes itself. It is not surprising that engineering solutions are offered as the only solution to defined structural problems, since it is engineers who are professionally legitimated to produce structures. John Chris Jones emphasizes that design should not be reduced to a static

metaphor of problem-solving. As he puts it, “to think of designing as “problem-solving” is to use a rather dead metaphor for a lively process” [55], since design is about opening new possibilities and testing our responses to them [55]. The tendency to solve problems is an exclusionary move. To explain this, consider Cedric Price’s statement, “the best solution to the architectural problem is not necessarily a building” [56], and ask yourself “How many times has happened that the solution to a structural design problem was not a structure?” This is unfortunate because it clearly exposes the closed-loop tendency of experts that operates in this way: It is the experts who define the profession, which dictates the practice, which produces the structures, which in turn define the knowledge of the experts. If structures are removed from this equation, then what is left for the profession, or, better yet, what is left of the profession?

John Forester suggests a solution that embraces contingency and rejects the use of the problem-solving approach. Instead, he offers the “sense-making” approach: “Sense-making is not simply a matter of instrumental problem-solving, it is a matter of altering, respecting, acknowledging, and shaping people’s lived worlds.” [57] I say that this approach embraces contingency because it brings about an acceptance of the social situations in which the design is first initiated, as well as the social situations with which the buildings and their users will later face. One of the reasons why the detailed design phase receives greater attention compared to the design concept is that it is one of the aspects of the design process where the structural designer has the most control. Although this control over the design is largely mediated by the actions of clients, cost, builders, government, etc., structural designers dream in their offices about their design ideals. In this isolated world, the self-interest of professionals leads to a kind of blindness to the situation and demands of others. However, with the return from object-making to sense-making, designers are also forced to take responsibility for the ethics of their actions. The actions that structural designers undertake are not supposed to provide generic solutions to specific problems. This is not about the structural designer who deals only with problems of form and technique, but about a person who deals with the gathering of conflicting voices in a given situation and extracts some kind of spatial and social sense. If there is hope in design, it can come from the reconfiguration of social relations, not from the false hope of form and technique. If we accept that social relations are part of the design process, then the structural designer has a special role to play in this reconfiguration: the role of mediator.

Regarding other values that a structural designer must possess to embrace contingency, Till advises that one should begin with the conditions at hand, responding in ways that are both practical and imaginative, critical and visionary. He emphasizes that every context holds the potential for transformation, sustained by a tension between realism and imagination, since “we must be realists in order to become visionaries and we need an understanding of social life to criticize and enlarge our view of social reality and social possibility.” [8]

Understanding social life means having an eye for finding the cultural values of the time. Since structural design is a social activism, then, if there are values in this profession, they will certainly be part of the socio-cultural values. Pérez-Gómez emphasizes the role of culture in shaping human activity, noting that neurobiology now understands consciousness as continuous across all forms of life, from single-celled organisms to human self-awareness. “Despite obvious differences among different classes of biological entities, this realization is crucial: consciousness is not something “other” than life, like a “soul” added to our biology and which animals lack (as in Descartes's thought), but is actually inherent in life.” [58] For humans, he insists, culture is not an external supplement to cognition but is embedded within the very structure of the mind. Without social interaction, humans fail to develop language or symbolic thought, leaving the brain with no greater symbolic capacity than that of an ape. [58]

An example that shows the application of the titanic fist of culture on structural design is to study the reinforced concrete framed structure, and the reason why it is the most used system today. If we were to talk about 100% structural forms, then the structures of Nervi and Maillart would come to mind, which followed the isostatic paths of forces, bringing the efficiency of the material. Nervi exploited this principle to produce structures at low cost. For the Gatti wool factory, for example, a competition was initially held, and Nervi's project emerged as the winner simply because it was the cheapest of all the other variants. And indeed, linear logic would say that the most efficient structural forms should give the most economical structural forms. Then, why today the forms that follow the paths of forces are not the cheapest anymore and why are they so rare? Instead, straight lines and right angles dominate. One could say that the market dictates it, because the formwork and constructability are more complicated for Nervi's forms. However, the economics of structures do not depend on how straight a line is and how right an angle is. Shortly after World War II, the cost of concrete material was very high and labor was relatively cheap, so Nervi's forms were relatively cheap. The more they were to be built, the cheaper they would become as the formwork would be standardized, the workforce would be specialized, etc. And yet, this did not happen. Later, straight forms with beam-columns became cheaper. That said, we must understand that the reason for their use did not come from economic reasons, but the reasons were actually cultural aspects, especially those derived from the architectural values of the time. It was the demands of the modern spirit and then the architects who first dictated the use of the beam and column in modernism and then the engineers, who, always refusing to deal with problems of value, ironically took on the values of others and, in this case, embraced the beam-column framed system. The same argument can be made for the arch, which is not an ideal structural system. The vault is. Yet, the vault became an arch because of cultural influence. Therefore, when engineers proudly say that the beam-column framed system is the most efficient structural system, what they call “efficient” is in fact “cultural”.

3. STRUCTURAL DESIGN VALUES AS CULTURAL NORMS

Chapter 3

3.1 Demand for Order and its Contradictions

One might say that, since modern man has been so criticized, we should cut that time and pretend it never existed. This is precisely what the modern project tried to do and, as we shall see in this chapter, failed miserably.

“We live all the patterns of time simultaneously”, [41] says Melucci. He explains that time may unfold as a recurring circle of memory and anticipation, as a linear arrow directed toward an aim, as an intense concentration in the present moment, or as scattered, fragmented experiences. Reconciling these different patterns is often challenging, since each leads us to the threshold of the others. [41]

Not only this, but Melucci's saying holds merit for cultural values as well:

We live all the patterns of cultures simultaneously.

Therefore we can be sure that an aspect of modernity holds values even for the structures of today. The challenge is to actually find those values.

3.1.1 Demand for Order. The Case of Modernism

The first cultural era we will find structural values is the one who has played the antagonist in this thesis up until now; the era of the modern men. Despite the critics, I am clearly aware this era has influenced structural design the most, therefore, many of the cultural values of this period can be addressed as current structural design values of the present and hold merit even for the future.

In particular, I will discuss the architectural aspect of the culture of modern men: Modernism. That is because, if I expect to find structural design values in culture, architecture in general, being a transition between culture and construction can be a clear indicator of the influence of culture in structural design. Siegfried Giedion affirms this when he says that modern engineering works should not be judged solely through an engineer's lens or reduced to functional efficiency. What matters more, he argues, are the broader methods they embody and the emotional content they carry, anticipating later architectural expressions. [59]

The Industrial Revolution, with its immediate increase in production thanks to the formation of new factories and machines, changed the world in which we live. Its effects on feelings and thoughts were so great that “even today we cannot estimate how deeply it has penetrated into man's very nature, what great changes it had made there” [59], says Giedion a century later. This movement did not need to come and did not come as a political movement because

it directly affected the common man. “Everyone was inventing, from unemployed weavers, small hand workers, farmers’ and shepherds’ sons” [59], says Giedion. It manifested itself in the mechanical dolls that could dance or the devices that automatically produced music through mechanical gears, created by street artists. It was these small creations in everyday life that showed the modern movement had already entered everyone’s houses. It was a matter of time before it even touched the houses themselves.

When a new building material appears on the market, it takes a short time for engineers to develop structural methods and typologies appropriate to its characteristics, but the artistic sensibility takes even longer to accept this evolutionary step. Aesthetic hysteresis takes longer than it takes for technical adaptation. Consequently, a period of transition arises before the beauty of the new forms can be judged and their full potential explored. Even masterpieces of certain periods bear traces which, when examined carefully, reveal techniques corresponding to a more primitive time. For example, Torroja mentions this case: “It is well known that metopes and triglyphs in the Doric order were originally constructed in timber, and yet their expression in stone, above the architrave does not deceive us.” [3] Therefore, the transition this spirit needed to be embraced as values by architects did not turn out to be so simple.

In the nineteenth century, as in any period of transition where production methods were changing, construction was particularly important for the architectural values it contained. The potential of this period is shown by the first skeleton structures of that time. The modern project began long before the definition of architectural values. Giedion affirms this when he says, “For a hundred years architecture lay smothered in a dead, eclectic atmosphere in spite of its continual attempts at escape.” [59], and then he explains “All that while, construction played the part of architecture’s subconsciousness, contained things which it prophesied and half revealed long before they could become realities.” [59] Consequently, it is construction, not architecture, which first provided the data about the values of this period. Architecture caught up gradually. This process moved so slowly that, around 1900, in Europe, most of the buildings from which the modernist movement later inspired, had no connection with inhabited houses. They were factories, warehouses, depots, etc., which, not being under the jurisdiction of architects, were the first to embrace the new spirit of modernity. Regarding this dualistic reality where art and science were moving in different directions, Giedion observes that contemporary artists and scientists have become disconnected, each speaking the language of their time within their own field but unable to recognize it in the work of others. A leading physicist, for instance, might not understand a painting that expresses ideas parallel to his own, just as a great painter may fail to appreciate architecture shaped by similar principles. Likewise, poets whose work embodies the spirit of the age may remain indifferent to contemporary music of the same character. Giedion attributes this fragmentation to the nineteenth century, a period in which the various spheres of human activity increasingly lost contact with one another. [59]

The great works of modernism reflect even now, after almost a century, the idea of freezing time and the optimism and hope that had overwhelmed the designers of that time. Alvar Aalto's sanatorium is inspiring with unwavering conviction in a better future of humanity and the success of the social mission of architecture. Le Corbusier's Villa Savoye makes us believe in the unity of beauty and logic and makes us believe that there are ethical and aesthetic values to this approach. The architectural modern movement influenced back at the modern project itself, and designers outside the jurisdiction of architecture started referencing architecture work of the time as the starting point of design's history. Such is the example of Bruno Munari, who explains in his book *Design as Art* that "Design came into being in 1919, when Walter Gropius founded the Bauhaus at Weimar." [60]

However, these works and these architects did not operate outside of time. Modernism itself did not happen like a sudden rupture but was influenced by cultural movements in the past. Colin Rowe argues that modernism has its roots in the continuity of history. He draws a parallel between 16th-century Mannerism, which transformed classical ideas and at the same time depended on them, and Modernism, which similarly challenged tradition by operating within previously imposed constraints. The Structural School, for example, which operated around the 19th century, was inspired by the Gothic Revival and by engineering logic and found the values of construction in materials, structure and craftsmanship. Architects such as Philip Webb and Berlage, who were part of this school, rejected pictorial effects in favor of structural clarity. As a result, this spirit led to the design of buildings that carried the tension of visual training and rational ideas. The Visual/Formalist school, represented by Norman Shaw, emphasized visual composition, eclectic style, and aesthetic values. These architects valued the pleasure of sight and broad impressions, and used historical motifs as stylistic devices rather than to create symbolic meanings. Despite their dual nature, truth and sensation were the two sources that laid the foundations of modernism. Rowe also finds commonalities between the Renaissance and Modernism. Although the former sought ideal, universal forms and sought to make that happen by dictating scientific and moral rules while the latter was more personal and sensorial, he says: "[They] both involve intellectual frameworks shaping artistic form." [31] To summarize, Rowe shows how Modernism in fact contained structural, visual and philosophical elements from previous periods. As such, it was not an isolated phenomenon but a synthesis and transformation of architectural values of the past. [31]

The spirit of modernism initially went very well with the pragmatic approach that engineers have had historically, which is why Le Corbusier mentions them so much in his book *Toward an Architecture*. He writes that the engineer, working from the law of economy and guided by calculation, aligns human effort with universal laws, while the architect, through the ordonnance of forms, creates an order that springs from the imagination. Engineers approach geometry as a mathematical tool, whereas architects often shy away from it. He insists on the need for standards to pursue perfection, pointing to the Parthenon as the result of applying

selection to a standard. For him, the law of economy governs both action and conception, making the architect's primary duty a revision of values and of the fundamental elements of the house. He calls on heavy industry to turn its focus to construction, standardizing housing components and fostering a "mass-production state of mind" dedicated to producing and preserving housing at scale. [61]

Engineers, according to Le Corbusier, were better architects in the sense that they built simple forms. The law of gravity, statics, and dynamics impose their sovereignty through a motto "stand up or fall down". The ruling determinism gives direction to the initial creation and gives assurance that something balanced and reasonable is being generated, which can be modulated endlessly, can evolve, vary and continue to be a unity. The architect, according to Le Corbusier, lacked precisely the pragmatism that most engineers had. "Architecture suffocates in routine." [61], he says. For example, it was absurd to him that wide retaining walls continued to be used even though a material like glass or lightweight brick had emerged. The same goes for foundations. "We still see enormous strips of piles made of masonry used for foundations even though simple concrete piles would be just as efficient. This is the influence of "styles", which are remnants of a past age; an unnerving timidity." [61] he says. Faced with a critical situation, Le Corbusier and others of his time decide to rebel not only against bad values—those that no longer represent the times—but against all values of architecture. Therefore, for him the house is simply a machine. If there are values, he finds them initially only in science and technology. "Objects have no soul, they are tools." [61], he adds. Therefore, he asks his colleagues to continue on the path of engineers and to move away from notions of art. For him, science will reach perfect forms and the architect, first and foremost, must be an engineer. "Housing will finally be a tool, like the automobiles today." [61], he concludes.

Steel, light metals such as aluminium and other materials such as concrete, glass, timber, rubber, plastics all began to be used on a large scale in construction in the modernist period. Riveting was replaced by bolting and welding, the first applications of pre-stressed reinforced concrete began, the correct ratios and formula of concrete were mastered, as well as techniques for its curing. Timber replaced wood for structural systems. The rigidity and resistance of the new structural systems made it possible to build wide-span structures. Another change was the abolition of the partition wall from its previous duty as a load-bearing structure. Instead of walls carrying and transferring loads from above to below, these loads were transferred through steel or concrete frames. New procedures were invented to test all these materials. New formulas and new construction and design methodologies were invented, which led to the possibility that spans could be expanded even further and rooms could have even more light. New alloys were discovered such as stainless steel, shatter proof, thermal glass, etc. Prefabrication was a process that, as we saw in chapter 2, was born from this era. All these and much more bear the hallmark of the modernist period. All these scientific achievements were made together with the social demands for mass housing. Post-

war construction dictated a mass-building project and standardization of products, but architects, according to Le Corbusier, were asleep at first, while the modern world was waiting for their action. [61]

Nevertheless, architecture can sooner or later give us an insight into the processes of understanding society in a given period of time, thanks to the fact that it is so closely linked to life in that period and in every period. Everything about it, from the preference for certain forms of approach to various building problems, reflects the spirit of the time from which architecture has flourished. It is a product of all sorts of factors taken together, such as social, economic, scientific, technical, etc. However much a period may try to hide itself, its true nature will still be revealed through its architecture. We can recognize the character of that period as easily as we can identify the handwriting of a friend, however much he tries to hide it. Yet, an architecture can also live as an independent object. Its influence can continue even after the spirit of the time has changed. That said, architecture can still influence, after the period in which it was created, after the social spirit by which it was inspired, and after the disappearance of the style and methodology with which its design was produced.

Colin Rowe explains that, like other spatial systems, the International Style was shaped by a rethinking of the roles of the column, wall, and roof. At its height, it proposed a skeleton frame where structural support was clearly distinguished from the non-structural task of enclosure. This made bearing walls—or even their appearance—unnecessary. As a result, columns were expected to stand free within the open space of the building, while walls, no longer tied to structural duties, could be arranged as independent, freely placed screens. [31]

The principles of this system were introduced in 1926 by Le Corbusier who published a list of diagrams which at that time represented according to him the logical effects of a reinforced concrete system. Around the same time, Mies van der Rohe, uninfluenced by Le Corbusier's work, reached almost the same conclusions regarding the study of steel structures. Following these findings, new requirements were drawn up for building structures, with new typologies such as columns, partition walls, a facade independent of the structure, as well as new requirements for roofs. As for the latter, for both practical and sentimental reasons, it was required to be flat. Le Corbusier wanted to use the flat terrace as a garden, while Mies van der Rohe preferred it because according to him, it was more expressive than the sloping roof and expressed the new form better.

Further, it can be said that the new style initially prohibited the appearance of beams and required continuity of floor plans. This condition was related to the concept of the free column. The free movement of the column in plan should not depend on the beams it supported, since it was assumed that the column and the floor above it were free and unrestricted from each other. If the beams were made visible, this idea would be weakened, because their presence as an intermediary between the column and the slabs would mean

that they would both be conditioned by each other. Mies van der Rohe transformed the sections of the steel columns from “O” to “+” sections and then to “H” and “I” sections. The previous sections tended to push the partitions away from the column. The new sections tended to bring them closer. The old “O” columns offered very few obstacles to movement in space, which removed those elements from the architect's attention, while the latter required more explanation from the architect. The “O” column tended to bring the space around itself, to be at the center of the volume, but the new column on the contrary acted as an enclosure or as an external definition of the space. Consequently, the characteristics that the two brought were quite different. The new column was embraced by the modernist style because it was more expressive than the old column. It could express, among other things, the existence of an autonomous structural system, which could be expanded by multiplying it with other columns that became part of the same system. After this transformation, the column could no longer be allowed to travel independently under the slab. For the first time, around 1944, it was shown connected to a network of apparent beams, and these beams set predetermined positions for the slab (fig.38).

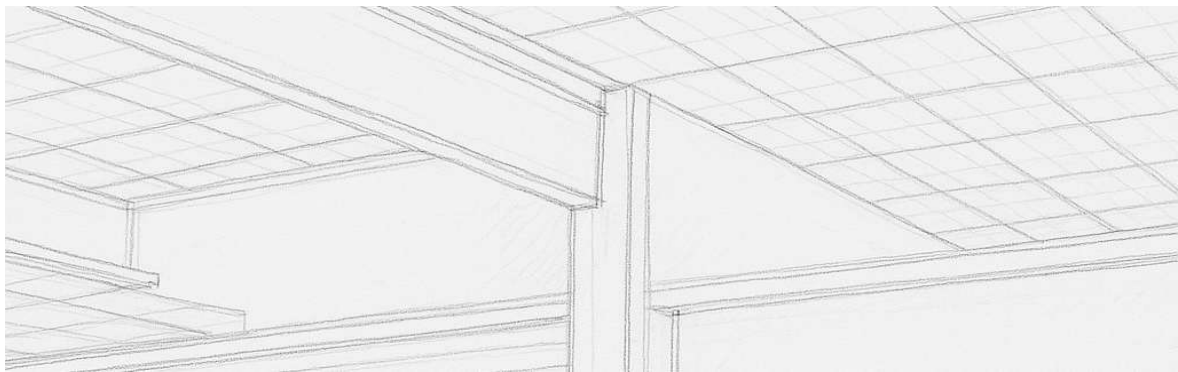


Figure 38 - Joint sketch of IIT Library and Administration Building in Chicago

Colin Rowe suggests that Mies van der Rohe's accomplishment was so innovative it may even have unsettled him. In earlier works, Mies van der Rohe had designed symmetrical projects, but these were conceived mainly around the column, and in the Reichsbank and Krefeld projects, he carefully treated principal volumes as distinct entities. In this new approach, however, he abandoned such separation, merging spaces into as continuous a whole as possible, while at the same time resisting the conventional International Style method of handling continuous space. [31]

Then, to support the thesis that the architecture of Mies van der Rohe and Le Corbusier did not represent only their personal values, but actually represented the spirit of the time, Colin Rowe suggests that their's architectural propositions—though less extreme—stemmed from broader assumptions about the nature of building and society. Thus, he argues, a building by Mies, whether successful or not, is always a commentary on the world rather than a self-contained statement. Moreover, despite the idealism of their positions, both Mies and Le Corbusier acknowledged and accepted what he calls the normative condition of twentieth-

century construction: the flat slab supported by points. [31] As one of the representatives of structural design in Modernism, Torroja, best explains the design values at that time: “Among these trends special emphasis might be placed on the style that values the aesthetic expression of the strength functionality of the design.” [3]

It was logical that structural design values should also be embraced by architecture. Modern design, always favoring the logical, accepted structural values as general values of construction. Confidence in them was also great thanks to the obvious achievements of the time in terms of techniques and materials. Characteristics of structures such as strength and deflections had never been so well known until that moment. Which meant that they could finally explore the materials they had at their disposal as never before. As a result, structures acquired a great personality and variety. There was more opportunity, as well as more desire than before, to fuse artistic and structural qualities. This was especially true of those works, which, because of their size and function, became entirely structural, that is to say, their design rejected all ornamentation.

The spirit of Modernism is better explained in the writings of the designers of that time, who, strangely enough, represented almost the same voice, as if in unity. Torroja, echoing Le Corbusier and Mies van der Rohe, argues that in the modern era there are more possibilities—and a stronger conscious intent—than ever before to unite the artistic and structural dimensions of architecture. This is particularly evident in works whose size and function make them purely structural, where their character is reinforced by the absence of superfluous ornament. Here, beauty emerges from the clarity of outline, the balance of proportions, and the rhythm of form. For the first time in art history, he claims, structure has gained its own independent personality, allowing its intrinsic aesthetic quality to be recognized and valued. [3]

In architecture, in general, it was required that spaces and volumes indicate—or at least derive from—their true purposes. For example, it was required that a good part of the exterior of the building indicate in some way what it contained inside, as well as indicate the purpose of the main functions of that building. This, as Torroja puts it, came naturally and there was no need for architects or structural designers to establish norms. [3] The fact was that in their time the relationship between form and its function was considered a virtue and symbolic ambitions were no longer considered a value.

As for the demand for structural expressiveness and the abandonment of ornaments, these characteristics did not come only from economic factors, despite the fact that economics was very important. Above all, there was the desire to obtain a complete solution to the problem of aesthetics. The artist did not allow himself to seek help from false techniques such as ornamentation. Regarding this idea, many structures that were previously rare began to be used, such as suspension bridges, which could offer emotions only thanks to the way they

resisted loads, without having ornaments. Structural designers found refuge in the simplicity of their structures and accepted it as a value. Thus, Torroja expresses it: “Yet it is also true, most profoundly true, that in the most pure aesthetic emotion (as in so many other things in life) simplicity is a virtue.” [3] He adds that attaining success with limited means often calls for sharper artistic sensitivity and greater effort than relying on unnecessary aids. [3]

Another value of design at that time was structural sincerity. The craze for demonstrating the structural performance of the building was so intense that it was no longer enough merely to avoid deceiving the observer with ornaments or with forms that seem to defy gravity. The modern project went so far as to require that the structure be stripped and revealed. “The motto of our age is the Delphic inscription ‘nothing unnecessary’” [3], says Torroja. If any sign of ornament was to be allowed, then it had to be clearly presented, separated and in contrast with the simplicity and sincerity of the structure so as not to defile the personality of the latter.

Symbolic meanings were all abandoned by the modern project and all values were placed at the service of technical and economic functions. If, for example, you were to visit a modern church, you would have to look at the cross or the form of the windows; otherwise, you would not realize that you were inside a secular hall, for which in any case the acoustic and thermal conditions had been met as never before. The modernist movement was essentially the idea that by improving as a society we would eventually reach enlightenment and that the efforts of the present would be rewarded in a perfect future. Hope and optimism were the two aspects that represented this movement and you can find them in all the texts of the designers of that time:

Inevitably, positivism, which has invaded everything with its unfortunate consequences, has also dominated the art of building. Even so, the sense of beauty has not been lost, and if we know how to interpret it, we shall learn to value this era of transition in which humanity struggles, so often mistakenly, to reach another better stage in its evolution—a stage in which its most deeply felt desires shall triumph and shall find an appropriate expression in new forms and techniques of construction. Humanity could rest in its peregrination, when it could recover that peace of mind essential for refinement of its artistic feeling, when it could find leisure to repeat and elaborate its basic types (as it did with other styles), and when the anxious present period of uncontrolled originality will be over, these tendencies and ideas of today shall mature. Works shall arise, as perfect as those of the classical eras. There is no essential reason why this should not be. For indeed the problems and possibilities of this age are greater than they have ever been. (Torroja, 1962) [3]

As for the connection with nature, biomimicry did not go well with the modernist movement, nor with the structures of that time. Construction work was accepted as artificial work and

this was a good thing for them because they associated this connotation with the builder as a producer, not with artifice as a concept of falsity. For them, construction offered something more than nature. It had a personality, a purpose, a form of execution that made it independent of nature. As such, a construction work should rhyme with the surrounding environment, not try to copy it. In some cases, as Torroja admits, the structure could even be accepted as contrasting with nature and the power of construction could dominate it.

Although the structural designers of the time would deny aesthetics as a value in design, Torroja admits that, despite this fact, he would feel appreciated if someone translated the simplicity, rationality and functionality of his structures as beauty. This was in fact the whole point they wanted to achieve. They were not against aesthetics. On the contrary, they welcomed it, but they did not want aesthetic values to be achieved by accepting the unplanned, disordered, heterogeneity and complexity in their works. Harmony and rhythm were what were valued most. With the exception of corrections necessary due to architectural issues, modern structural designers believed that structural beauty was achieved only thanks to structural form, and the characteristics of its load-bearing capacity contained a kind of expression of itself. Furthermore, they thought that if their work were essentially structural, aesthetic values would appear by themselves. Even the artistic values of the modern era actually preferred what was simple to what was complicated. Both structural designers and architects hated to be deceived, and they despised ornament. Neither side showed a tendency towards biomimicry. Both liked harmony and rhythm. The tendencies of the time liked to show the importance of the material and to minimize economic and constructability objectives. When this vision clashed with reality, the modern project once again unanimously blamed society, which for them was transitory and would one day have enough emancipation to properly evaluate the works of the time. The best structures at that time, as mentioned, were the expressed ones. If they were not exposed, there was still hope for aesthetic values of the work, which could be achieved by designing these structures with maximum strength and minimal cost. To understand this mindset, let us recall how Torroja compares these structures to the woman skeleton. In itself, it may be unattractive, but becomes the trigger for the creation of attractive forms, which for him are represented by the body of a woman. Therefore, for him, as long as the skeleton highlights the values of the whole, it still carries aesthetic value. [3] Yet, Torroja also implies, “In no architectural style, or better still, in no constructive technique, has the load-bearing structure been so entirely independent of the whole work as in contemporary structures” [3] The structures of that time also carry other aspects of modernism; that of the standardization and self-referentiality. If there is one indicator that represented the modern spirit, it is, according to Peter Eisenman, the tendency of the object to be self-referential. [62] As such, the structures were seen as having a personality entirely of their own, separated from architecture. Indeed, the tendency was for structures to exist for structures' sake. The only cases when structural designers worried about the meaning of things were only when they had to deal with structural

problems alone, as if this were independent of other activities. This idea had its benefits. As Giedion observes, with technological advancement, even unskilled labor has been transformed, since every position has become accessible to all. Specialization binds each worker to a machine, enforcing exact precision, as no step in the process can be corrected by the next person—it must fit seamlessly into the whole. In this system, “The father no longer teaches his son the myriad secrets of his craft; an unfamiliar foreman strictly controls the rigorous performance of a limited and circumscribed task.” [59] The worker’s role becomes narrowly defined, sometimes lasting years or even a lifetime, and he sees the result of his effort only in the finished product. [59]

The second indicator that characterizes the modern spirit was standardization. Standardization embodies a mixture of the best characteristics of the element, thus eliminating the individuality of that element. Standardization of processes led to the structure being less dependent on the weather. Although modernism tried to standardize everything that had to do with the building—as in the case of prefabricated houses—building designers never stopped seeking freedom of design. As a result, mechanization never managed to transform the building into a tool. The spread of machinery destroyed the old way of production, but it was the materialist mentality, according to Gropius, and the defective and new articulation of the individual that guided the Modernism movement, not the machines themselves. [59] The machines themselves were not considered salvation at all. They were seen like any technology throughout the different periods: with potential and with fear. Giedion puts it as follows: the present age must recover what it has lost—human scale, individual rights, and the basic security of moving freely within the city. In earlier times, people had comparatively easy access to the land, whereas today even the simplest needs are difficult to satisfy, a condition brought about by the oppressive burden of mechanization. [59]

For Torroja, the successful structures of earlier times that did not carry the same values that modern times offer were either wrong, or else, for those that were close to his heart, a well-trained audience was required to perceive their “sincerity”. This audience had not yet been achieved, but there would come a day, according to the modern project, when modern man would be well-trained enough to finally enjoy the internal skeleton of buildings. Such is the case of the dome of Saint Peter in Rome, for example. Its shape clearly deceives observers by hiding its supports. But for Torroja, its shape requires the observer's eye to have some kind of fourth dimension to understand the depth of space while standing below it, about 130 meters away, and to perceive that, in fact, the supports are hidden somewhere inside. How absurd is this? And why is this structure different from a simple structure that Torroja condemns as insincere? Nevertheless, modernists defend this argument with the fact that the human mind learned to treat reinforced concrete, not as artificial stone, but managed to perceive the reinforcement within it. This was achieved with the emancipation of society, without the need to draw the reinforcements on the surface of the concrete.



Figure 39 - Mies van der Rohe, National Gallery, Berlin 1969 & Crown Hall, Illinois Institute of Technology, Chicago 1956 (adapted from Schumacher, 2022, p. 39&40)

To reduce complexity, the modern project used the strategies of decomposition and uniformity. In both examples above (fig.39), the principles of modernism are clearly applied. The typology of the system shown, the uniformity, the decomposition into discrete elements with controlled force distribution in joints, standard industrial elements (I-beams). Specialization took over the construction systems. The wall of a building required different materials for its load-bearing frame, for thermal insulation, as well as for the exterior. Strangely enough, although it is only the last layer visible, for modernists this is not a desecration of the sincerity of the system. The reason for this remains society, which according to modernists must have eyes to see through the wall.

Regarding this topic, Torroja emphasizes the decisive role of perception in judging architecture: “This is a very important aspect of the matter: the quality of the observer. We admire the Athenians because, so tradition has it, a common woman could instantly improve, at a public competition, a faulty verse of the best poet.” [3] By contrast, he laments, “Unfortunately our society has not yet attained that level in criticizing the artistic perfection in construction, and our critical ability should improve.” [3] Until then, he argues, structural designers must seek the approval of a discerning minority trained in both aesthetics and structural mechanics. Just as musical culture allows one to perceive the deeper subtleties of a composition; technical understanding enables an observer to grasp the true character of modern structures. Without this knowledge, people risk misjudging innovations—for instance, mistaking a reinforced concrete transom, correctly sized for its material, as a wrongly proportioned stone monolith and suspecting failure where none exists. [3]

For the Modernists, it was not important to theorize about feelings, nor values. They rejected the problems of forms and wanted to deal only with the problems of buildings. They were

concerned with technical problems and learning how to do things. Yet, at the same time, technical problems became for modernists values in themselves in which they saw the spirit of the time and aesthetic value. Gropius expressed this approach best when he explains that freeing architecture from excessive ornament, focusing on structural function, and pursuing clarity and economy represent the material dimension of the formalizing process on which the New Architecture's practical value rests.

What was first started as a rejection of aesthetic aspects by focusing on techniques was latter followed by an approach to find aesthetic values in these techniques. Mies van der Rohe explains that "It is radical and conservative at once." [30] Its radical side lies in embracing the scientific and technological forces of the age, drawing upon their methods and tools without being reducible to science or technology itself. At the same time, it is conservative, since it addresses not only purpose but also meaning, and not only function but also expression. Ultimately, according to him, "It is conservative as it is based on the eternal laws of architecture: Order, Space, and Proportion." [30]

Nevertheless, the 20th century had other peculiarities. With the consolidation of theoretical principles, structural engineering was no longer seen as a source of inspiration for forms in construction. Giedion explains that modern architecture often demands more from engineers than current methods can provide. [59] Structural engineering itself emerged from advances in calculation techniques and in the production of ferrous metals. For calculation purposes, structural elements were treated as linear components, with forces directed along prescribed paths and carried through these elements.

This linear approach naturally gave rise to prefabrication and standardization, with the Eiffel Tower serving as the most renowned early example. [59] Consequently, in 20th century structural design, the focus was on formulating units of different shapes that would better withstand loads, rather than on discrete elements that made up the structure. This led to the growing trend towards reinforced concrete shells and reinforced concrete walls, instead of the beam-column skeleton that had previously represented the modernist spirit. On some occasions, the structure become sculpture.

Nevertheless, these forms were valued mainly for their good technical performance first, and only after this condition was met, their designers would allow themselves to brag about their aesthetic characteristics. Examples of these designs were the work of Maillart, Nervi, Torroja, Candela, Utzon and many others.

The modernist spirit, after its consolidation, like all previous movements, found refuge in formalism, linking its values to certain forms and claiming that these forms had an ethical basis. "In Modern architecture we have operated too long under the restrictions of unbending rectangular forms supposed to have grown out of the technical requirements of the frame and the mass-produced curtain wall." [53], says Robert Venturi. Mies van der Rohe, for

example, did not allow any deviation from the rules he had predetermined for forms. The point, the straight line and the plane surface were his weapons for every occasion. He, for example, rejected the use of structural bracings because for him that form violated his principles.

Nevertheless, not all designers of the time were that radical. Louis Kahn, for example, as Venturi points out, accepted braced systems, “but at the expense of such vertical elements as the elevator and, indeed of the spaces for people.” [53] However, even in its early days, the modernist movement had taints of abstract motifs and the supposedly purely functional intentions were actually mixed with formalism ideas. Rowe points out that Giedion’s parallel between the Bauhaus and Picasso indicates that Gropius’s 1926 work did not entirely abandon abstraction; rather, it is precisely this abstract quality that distinguishes the Bauhaus from pre–First World War production. [31]



Figure 40 - Replica of Crystal Palace, Madrid (author, 2025)

The Palacio de Cristal, in Madrid (fig.40), is a replica of the Crystal Palace in London, which was burned in 1936. It was one of the symbols of the new spirit and the dream for a better life, which accompanied the entire period of the Industrial Revolution and the modern project, to find hope in science and to erase and deny the values carried before that period. Its destruction by natural causes (accidentally, by fire), ironically, shows the naivety of that dream. Nevertheless, anyone who had seen the real Crystal Palace was said to have been “blinded” and amazed by all that light, which people had not been accustomed to seeing inside a building until that time.

3.1.2 Contradictions of Order

Unfortunately, there comes a point when society simply gets bored and looks for something else. It is as Christian Norberg-Schultz says: “One of the reasons why the public reacts to modern architecture is simply that it does not offer any new visual order as a replacement for the ‘depreciated’ styles of the past.” [63] That said, although it is easy to treat Modernism as the antagonist that has deprived us of the freedom of design, we must be careful not to absorb dissatisfactions that comes from the desire to simply do something different because different, sometimes, does not mean better. This is all the more reason to weigh the values of Modernism and to see which of them still stand in the world we live in.

First, for many reasons, the concept of efficiency is simply irrelevant. It makes no sense to talk about the efficiency of a piece of furniture or the efficiency of a monument or the efficiency of the structure of Casa do Penedo in Fafe (fig.41).



Figure 41 - Casa do Penedo, Fafe, Portugal (author, 2017)

All engineers are obsessed with the idea that it might be possible to measure the efficiency of practically anything. However, this is not possible. Although it is almost certain that many engineers believe in a close connection between functional efficiency and other structural values, I am skeptical. Just look at the beauty of the structure. Gordon says that the concept of beauty comes from the moment of the artist's personality and the structural values accepted at the time. [17] The second aspect is important because it directly connects aesthetics with structural design values of the time. Therefore, speaking subjectively about the beauty of structures is a step closer to finding the structural design values of the time in which we live.

“Okay”, says an engineer, “but structures are not furniture. They must at least be functional, since the central technology of beauty is functionality.” If what he means by this is that things must do their job properly, then he is saying something that is known. However, when we seek to apply functionalism as an aesthetic criterion, we are going too far. There are certain structures, such as bridges, where the structural function is simple and obvious. Many of them are beautiful, but there are also some that are ugly. There are also a number of very expensive objects that are, of course, beautiful, such as, for example, Lamborghinis or Ferraris. But are we sure that in this case we are admiring only the perfection of functionality, and not some other factors? Of course, structures that are completely non-functional will look ugly, but I doubt that improving the performance and technical aspects of structures improves their appearance. Very often, it is quite the opposite. The tendency for pursuing efficiency to the maximum can result in a boring appearance. If science is to be blamed for anything, it is that “science has subtly distorted our value system by training us to judge on grounds that are too functional” [4], as admits Gordon. Modern man says, “What is this person or this object for?” instead of asking, “What is that person or that object?” Aesthetic evaluation requires us to answer important questions. It often happens that our scientific—or objective—evaluation clashes with our subjective evaluation. In the case of the aesthetic aspect, “we sweep aesthetic judgment under the carpet at our peril” [17], explains Gordon very subtly. Of course, there is no reason why a beautiful structure cannot also be efficient. However, these two aspects are not dependent on each other. The beauty of the structures of antiquity and Ancient Rome, for example, has nothing to do with efficiency. On the contrary, these structures were completely inefficient. The compressive stresses were extremely small, while the tensile stresses were often dangerously high. The structural solutions for the domes of old buildings, as we have already seen the example of the domes of Saint Peter, can be described as a real mess. Nevertheless, they are beautiful (fig.42).



Figure 42 - Saint Peter's Basilica (author 2023)

However inefficient these structures may be, they were usually expressed. Indeed, structural expression was valued by the modern spirit as an aesthetic aspect, but it was this same spirit that later hid the structural elements within the walls. Structural sincerity, too, as we saw in Chapter 2, has no real design value, since it assumes that structural form has ethics. Then, as for ornament, if modern critics condemn a covering of the structure as unsuitable or unrelated to what it is wearing, this may be understandable on some cases, but all ornament actually has some effect, and it is not always bad. Gordon argues in favor of decoration,

remarking, “It seems to me that what we want is more, not less ornament. The truth seems to be that we are frightened to express ourselves in ornament.” [17] Unlike medieval masons, who worked without such inhibitions and were likely healthier for it, modern society shies away from ornamentation. He insists that technologists should be asked not only to create functional artifacts but also to bring beauty and enjoyment into everyday environments. [17] As he warns, “Otherwise technology will die of boredom. Let us have lots of ornament.” [17] There is nothing wrong with Medusa's head on the deck of ships, lion symbols on bridges, statues on buildings, etc. On the contrary, if this is a way to express yourself, let us have more ornaments, since expressive power is vital.

Pallasmaa accuses modern design of having destroyed the sense of aura in buildings. Their technologically constructed products do not reveal the processes of their construction. This fact, and the craze to deceive the eye, such as the use of reflective glass for facades in Modernism, raises the concern that a parallel reality is being sought to manifest outside the norms of construction. “We are unable to see or imagine life behind these walls. The architectural mirror, that returns our gaze and doubles the world, is an enigmatic and frightening device”, [24] he says. In stark contrast, materials from nature such as stone, clay or wood, allow the vision to penetrate through their surfaces and easily understand the construction process. Natural materials also express their age and history, as well as their origin and the history of their use by humans. As a result, they show very well the continuity of time. Not only that, but also these materials, according to Pallasmaa, exhibit architectural values under the influence of time. [24] Whereas artificial materials, those made possible only by machinery and man, such as window glass, metal profiles, Portland concrete and synthetic plastics, do not exhibit the influence of time, at least not in the way architects would like. Steel corrodes and as a result, its properties deteriorate. Plastic disintegrates, concrete cracks, glass loses its transparency. The buildings of the Modernist movement, according to Pallasmaa, seek to achieve perfection independent of time. This weakening of the experience of time has brought about catastrophic mental effects. Gotthard Booth implies that “nothing gives man fuller satisfaction than participation in processes that supersede the span of individual life.” [24] It is the task of design to bring this experience back once more.

As for standardization as a norm, it is another manifestation of the rule. However, the Modernists did not establish it as a norm, but accepted it as an enlightening product of their era, while suggesting caution about its dominating potential and brutality. Gropius states: “mechanization would be an unmitigated calamity, robbing the life of half its fullness and variety by stunning men and women into sub-human, robot-like automations.” [4] However, as a last resort, he adds that its ultimate aim is to relieve individuals of physical labor so that their hands and minds can engage in higher pursuits. [4]

Robert Venturi was a loud critic of Modernism. For him, modernists were so fixated on mentioning what was different at the time, that they lost touch with what was actually the

same. [53] Otero-Pailos, while describing Kenneth Frampton's theory of Critical Regionalism, argues that modern architecture repeatedly collapsed into crises because it could not adequately express the advances of industrial construction. In this sense, modern architecture either never truly emerged or had already ended, leaving behind only building. [63] Frampton believed that architecture is the elevation of buildings to an aesthetic, that the existence of architecture is necessary to provide a source of individual experience for human lives, a way of experiencing shared reality. The problem is that, in the period of industrialization, it became impossible to transform the notion of the building into something more than mere construction and therefore, for Frampton, Modernism as a genuine architectural movement never took off. [63]

For Venturi, architecture should not be held hostage by a moral language dictated by Modernism. He wanted designers to have other alternatives beyond this dogma. He liked, for example, hybrid, compromising, distorted, contingent, perverse, boring (why not?), conventional, accommodating, and redundant elements. In stark contrast, Modernism dictated purity, cleanliness, sincerity, pre-designed, well-articulated, expressive and simple. Venturi particularly criticizes the concept of unity and demands that architects have the opportunity to design works also as messy vitality. [53]

He argues that an architecture of complexity and contradiction is accountable to the whole, finding its validity in a sense of totality. It should embody a challenging unity that embraces inclusion rather than the simplicity of exclusion. [53] "More is not less." [53], he says. Gropius complained that his architecture had been wrongly judged as rational, but amid simplicity and order, the process is worthy condemned of being so. [53] Since rationality is not suitable for representing life, it is not suitable for any social activity such as structural design or architecture in general. On the contrary, from contradictions and uncertainties, a tension is created that turns into equilibrium. Indeed, why not have a sense of paradox that allows seemingly different things to stand next to each other and their inconsistency can actually be valuable in itself. That contradiction is certainly truer than total unity.

Venturi writes that the maxim "less is more" dismisses complexity and legitimizes exclusion as a form of expression. While it allows architects to be "highly selective in determining which problems [they want] to solve", he argues that a true commitment to one's vision of the world does not grant the freedom to choose which problems to address, but rather defines how problems should be solved. [53]

The acceptance of complexity as a value in architecture does not negate the value of simplicity. But, as Venturi puts it, the aesthetic simplicity that brings an impulse of pleasure to the mind actually comes from an inner complexity. For example, the simplicity that the image of the Doric temples creates is achieved through the famous subtleties and precision of their geometry, that is, the contradictions and tensions present in the rules that that

structure followed. [53] So these temples were apparently simple, but if you look closely, they contain contradictions and complexity. If their apparent simplicity were rigorously applied to other temples of today, we would no longer have the simplicity that Modernism values, but only blandness.

According to Venturi, not all simplicity has values, as well as not all complexities have values either. What Venturi names as “fake simplicity” and “fake complexity” are new formalisms that are unconnected with life that do not reflect genuinely complex programs. Such forms, according to Venturi, are the ornaments that are dependent on industrial techniques whilst originally where made by hand. [53] It seems that even for him, there are some formal acts that are deemed to be unethical regarding buildings.

Although Gropius's book is called *The Cultural Obligation of the Architect*, the feeling one gets when reading it is that he is in fact proposing the cultural obligation to the architect. Among other things, he writes: “A feeling for beauty and quality, when it spreads into all levels of society, nourishes the creativeness of the artist and gives him the needed response.” [64] In connection with this and with all the demands that modern design made on society—such as having an extra eye to see beyond walls or to understand the distribution of forces even when the structure is hidden—there are signs of narcissism in the idea that it is the duty of society to produce the right environment to satisfy the aesthetic impulses of the designer. There is a kind of pattern in this behavior that we see in every well-established movement. The avant-garde will never go beyond the conservative systems that it seeks to criticize, because, in the end, both are framed by the same system values, namely that of production of taste. We find it everywhere. From classicism, to modernism, to post-modernism (which tends to establish an equation between complex forms and ethical forms). Even in our heroes, like Venturi, we see that they sometimes confuse their morality and tastes with the ethics of forms. It is precisely as Reyner Bahman projection of this case: “...the studio as setting establishes attitudes and values that are then played out in the black box of the profession. Intrusions from outside are restricted in order to allow the internal processes to develop on their own terms.” [65]

In the absence of formal rules for synthesizing the structural form, Cleanth Brooks argues for a phenomenological reading of poetry, noting that poets often embrace ambiguity and paradox not out of rhetorical vanity, but because their role differs from that of the scientist. While science dissects and classifies experience into parts, the poet's task is to restore its unity as it is lived. By dramatizing this oneness while still acknowledging diversity, the poet's use of paradox and ambiguity becomes a necessity rather than ornament. In doing so, poetry offers insights that preserve the wholeness of experience, reconciling contradictions and conflicts by weaving them into a newly unified pattern. [66]

In addition, in contrast to strict formalisms that do not represent life, design can carry contradictory architectural values that involve the word “yet”. [53] Le Corbusier’s Villa Savoye is simple on the outside, yet complex on the inside. Shodhran House is closed, yet open because it consists of a closed cube, yet with openings on its surfaces in a random manner. Frank Lloyd Wright’s Fallingwater appears as an extension of nature, yet asserts itself is an autonomous man-made object. Mies van der Rohe’s Barcelona Pavilion is free-flowing in plan, yet its materiality is both monumental and heavy. Tadao Ando’s Church of Light is minimalist and austere in terms of material, yet dictates a spiritual richness thanks to the single incision of light. The exterior walls of the Alhambra are stuccoed on the outside to further express their surroundings, yet full of ornaments on the inside to draw attention to them (fig.43).



Figure 43 - Alhambra, in and out (author, 2025)

None of these formal characteristics represents beauty, but neither do their opposites necessarily represent the whims of the designer. It is perhaps the contradictory nature they carry that Venturi considers valuable in design. Similarly, Venturi argues for and values forms that carry the notion of “both-and” rather than the notion of “either-or”. He says:

Cleanth Brooks refers to Donne’s art as “having it both ways”. Nevertheless, he says, “most of us in this latter day, cannot. We are disciplined in the tradition either-or, and lack the mental agility—to say nothing of the maturity of attitude—which would allow us to indulge in the finer distinctions and the more subtle reservations permitted by the tradition of both-and.” The tradition “either-or” has characterized orthodox modern

architecture: a sun screen is probably nothing else; a support is seldom an enclosure; a wall is not violated by window penetrations but is totally interrupted by glass; program functions are exaggeratedly articulated into wings or segregated separate pavilions. (Venturi, 1966) [53]

“Both-and” cases can be elements that are both good and awkward, large and small, open and closed, structural and spatial, honest and false, etc. He sees these contradictions and ambiguities with optimism and welcomes them. For him, an architecture that carries several different levels of meaning causes tension.

Elements with multiple functions are rare in Modernism. The reason is that modern design has supported specialization and unity at all levels, from materials to structures to procedures and spaces. In Modernism, the tendency was to use materials only for a specific function. Wright, for example, unlike his teacher Louis Sullivan, said that materials assigned to one project or part of a project could not be used for another project or part of a project. [53] However, the facade of Frank Gehry's Guggenheim Museum is clad in titanium panels, glass curtain walls and limestone blocks, and yet the fluid forms give the impression that the surface is continuous (fig.44).

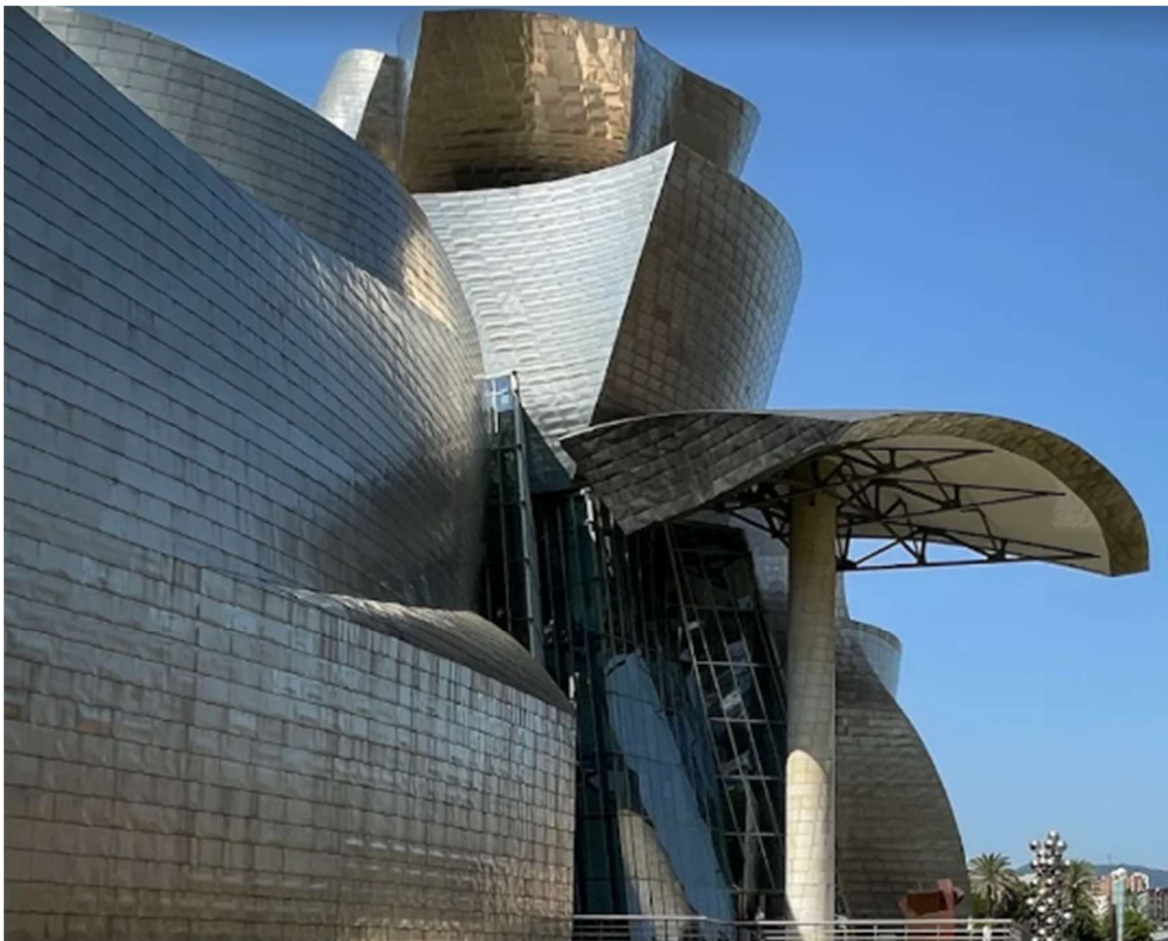


Figure 44 - Guggenheim Museum Bilbao (author, 2025)

In such works, the medium is strained because there is a contradiction of levels of function and meaning. However, for a pure structuralist, structural form that plays the role of several functions would be bad because of the mismatch and ambiguity between form-function and form-structure. The sections for the bamboo elements for the Aura Villa in Bali (fig.45) do not depend on forces, nor on the way they work—it does not matter whether they work in compression or tension. Even the sections of bamboo used for the staircase handrails are larger than the sections of the structure itself. A modernist structural designer would find this strange and would not be comfortable with this idea.

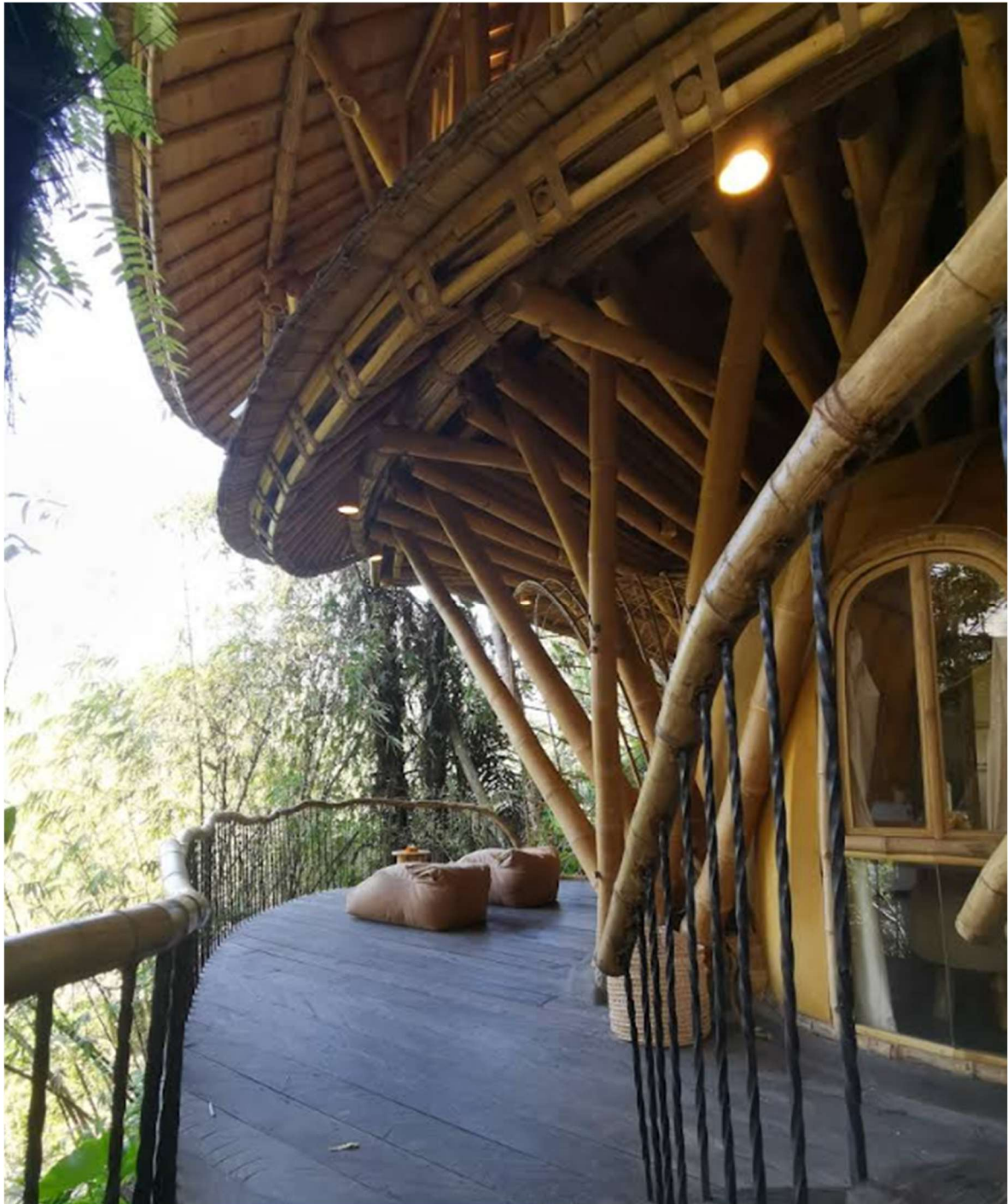


Figure 45 - Aura Villa, Bali, Indonesia (author, 2024)

The stairs of a building in Turin (fig.46) have a supporting structure that also serves as a handrail, while the treads are non-supporting elements. To a modern structural designer, this would seem catastrophic.

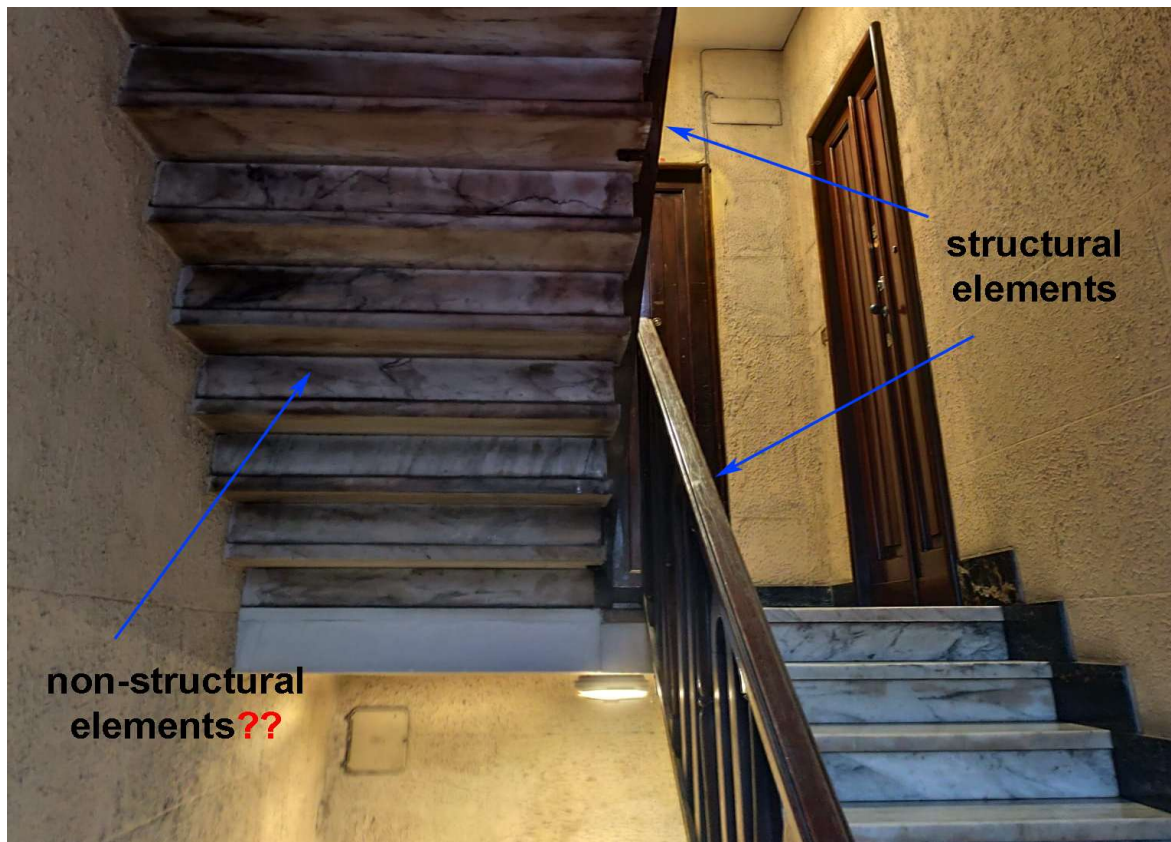


Figure 46 - Stairs, Turin, Italy, photograph by Jonida Alliaj, 2025, used with permission

Modern design requires us to separate and articulate elements. Modern designs are never implicit. By promoting the skeleton and the curtain walls, they separate the structure from the architecture. Even in the details, modern design seeks to separate and make everything clear. However, even within the Modernist movement there are some exceptions. In Le Corbusier's Unité d'Habitation, the brise-soleils are both structures and sunscreens. The columns in Kahn's Richards Medical Center project are neither entirely structural nor have efficient sections. He uses them as supports, but also to "play" with light.

Flat slabs are an example of contradiction in design. They consist of a relatively thick section compared to other slab typologies, reinforced with longitudinal reinforcement and with additional reinforcement near the columns. They are used because they provide ease of implementation and because they allow the architect more freedom in dividing spaces. As a result, the demands for structural performance pale before the demands for livable space. Form follows function in this case in a strange way. The type of material and its form follow the structural function while its section and typology follow the architectural function. In other architectural works, the column, the arch and the retaining walls all share the same role: the aesthetic role for the facade and the functional role to bear the loads.



Figure 47 - Nasrid Palaces, Granada, Spain. Pilasters as both-and elements (author, 2025)

The balloon frame, the system used for the first wood-frame houses in the USA, is both structure and shelter. As such, designers are concerned with its load-bearing capacity as well as the gaps that must be accommodated using this system to allow light to enter as well as to shelter what is inside from what is outside. This system is therefore impossible to be categorized into standard typologies. The step between modules is too small to be categorized as a structural frame and too large to be categorized as a whole surface. A valid order accommodates the contradictions that come with the complexity of life. As it accommodates them, it also imposes them. Venturi argues that proper architectural order both accommodates and imposes, allowing for “control and spontaneity” and “correctness and ease”, or improvisation within a coherent whole. Such an order accepts compromise and qualification, acknowledging that while there are no absolute laws in architecture, not every solution is viable. It is therefore the architect’s responsibility to make subtle judgments: to determine what must be resolved, where compromises are acceptable, and how inconsistencies of program and structure can be integrated into the overall order rather than excluded. [53]

Mies van der Rohe seeks to create order out of the confusion of time itself. But beyond that, if we resist the fear that this confusion causes us, we can search for meaning within the complexities and contradictions of time and accept that systems are limited. The variety and confusion of systems at every step of the process cannot be a justification for establishing strict rules. On the contrary, they are reasons why we should break the rules depending on

the situation. As Venturi admits: “When circumstances defy order, order should bend or break: anomalies and uncertainties give validity to architecture.” [53]

The meaning for Venturi must come from breaking the rule. A building without imperfect parts cannot have perfect parts because contradiction is what opens up the meaning. However, Venturi does not praise chaos either. He explains that we can allow contingencies all over the project, but they should not prevail. If the rule without the situation gives formalism, the solution of the situation without having an initial rule gives chaos. The rule must be formulated once, in a general way, before being broken, depending on the situation. Even artists, who are supposed to have freedom for their creativity, do not operate without a basis established by general rules. Therefore, the rules stay. The only things to be embraced here is contingency. It may seem like a simple thing, but usually the opposite happens; in structural design jurisdiction, whenever someone “breaks” a rule set by the design community for the good of their project, others behind them tend to exaggerate the hegemony of the rules. For example, if someone designs a structure that is apparently vulnerable to earthquake forces, the structural engineering community compiles a series of papers to restore the order violated by this act. They blame the form and go so far as to demand the use of only regular, simple, structurally efficient forms, etc. What no one wants to understand is that it is the situation that dictates the project and, as long as the designer argues that his structure is safe (he certainly does this and bears responsibility for this), then the form can be done differently. The 2019 earthquake in Albania proved this argument.



Figure 48 - A building in Durrës with 15 additional stories above the old structure (author, 2016&2025)



Figure 49 - Plaza Tower, Tirana (author, 2025)

A tall building in Durrës (fig.48) that stands out for its contradictory form has been endlessly judged in the auditorium because apparently the builder has added almost fifteen additional floors after the construction of the initial building. The structure of The Plaza (fig.49) has a much smaller base than the sole of its top floor. All the slabs increase their surface area in height. I remember that when we passed by it one day, during its construction, my father, who was a builder, commented worriedly: “These people are crazy!” During the 2019 earthquake, neither of them had any problems, while some buildings next to them with more regular shapes collapsed. Clearly, both designers in this case had taken into account the contradictions of their constructions and had acted to secure their buildings even against a notorious event like an earthquake.

A complex architecture does not deny the whole. In fact, Venturi suggests special attention to the whole because it is, according to him, difficult to achieve. [53] In fact, he values the purpose of the whole differently from the Modernists who believed in the simplified concept of Unity. He is for the difficult unity that accepts all elements instead of the simple unity that excludes elements. [53] Gestalt's psychology considers that man experiences a perceptible Whole from the presence of its parts. As such, it is dependent on the position, number and characteristics of each of its individual parts. However, the observer creates a completely different perception of the whole, rather than observing its parts separately. The difficult unity in a complex and contradictory architecture involves the diversity and multiplication of elements in unequal relationships. Regarding the positions of the parts, for example, a contradictory architecture encourages complex and contrapuntal rhythms compared to a modern architecture that can offer a dull rhythm. However, a complex architecture also accepts steps outside the rhythm. The duality, the presence of contradictory elements nearby, the presence of different natures and characteristics nearby. He welcomes all this. Then, Venturi suggests the third value—after the “both-end” and “yet” nature of the elements—in design; Inflection. [53] By inflection, he assumes precisely this ability that the elements have to not be perceived as whole, which allows the observer to create a completely different perception of the whole. [53] The observer is not able to distinguish the exact number, nor the exact position of the elements. He judges with an unclear perception and, at the same time, is influenced by the partial characteristics of all the elements together. The fragments that the observer experiences from each element combined imply richness and meaning outside themselves. Consequently, this particularity of the building elements makes them not only with several functions and with contradictory functions, but also with partial functions, depending on the situations. As far as the situations are concerned, they highlight certain characteristics of each element, thus bringing about a perception of the whole, different from its constituent parts.

For Bauman, the modern project is a constant struggle against ambivalence. However, life does not work like that and diversity must be respected.

As Till says:

To go to the furthest shores of humanity is to begin to understand that the war on ambivalence and the ridding of contingency are not benign processes. It might appear that the normalizing pursuit of order and certainty is self-evidently sensible. But in fact the normalizing disguises a stealthy process of the marginalization of difference. What is normal to one group may be abnormal to another. Le Corbusier's abhorrence of the “general uproar” is the other side of his will to impose his value system. (Till, 2009) [8]

The versions of modernity that accept their contingency accept postmodernity not as an opponent of modernity, but as its actuality. "Postmodernity [is] modernity without illusions...modernity reconciled to its own impossibility" [53], said Bauman. He, Till, and many others share the view that postmodernity has not only come to terms with contingency, but has committed itself to live with it, for better or worse. For worse is the key word here, since for reasons independent of design, chaos sometimes prevails and we must know how to deal with it.

One way of its manifestation is the literal chaotic construction. The constant bombardment of unrelated pictures and images, accompanied by the chaos of site-construction and buildings and the advertisements that appear on their walls, leads to a vacuum in terms of emotional content. Even in their intended appearance, which is when the work is regarded as complete, images of buildings are endlessly served as mechanically produced comforts. As a result, people become addicted to this bombardment, without having the opportunity or the courage to face the existence of an alternative for themselves. "We are made to live in a fabricated dream world." [24], concludes Pallasmaa. Contemporary buildings have had their share of faults in this whole process. Their facades today seem more important than the interior spaces. Eileen Gray observes that avant-garde architects often privileged the exterior appearance of buildings over their interiors, designing houses more for visual impact than for the comfort and wellbeing of those who lived in them. [24] Frederick John Kiesler blames the functionalist approach and the building industry. He believed that functionalism conflicts with lived life. What functionalism actually does, according to him, is only to standardize and condition habits. As such, functionalism is self-referentiality disguised as design value. "It enabled a foot to walk but not to dance; an eye to see but not to envision; a hand to grasp but not to create." [67] Buildings, according to him, should respond to dreams and a cosmic order that unfolds thanks to light-shadows, colors, dimensions, etc., that interacts with the inhabitant. In this way, space is never made simply functional. Instead of functionality, the value of buildings for him was in the atmosphere they created and in the quality of the liveable space. [67]

3.2 Returning to One's Senses. The Case of Tectonics

Independently of Venturi, many of his contemporaries felt the idea that the building is a contradictory object, and this was reflected in their obsession on strengthening the identity of the profession. “The first response to change is very often denial”, [63] says Otero-Pailos on this case. In the post-modern era, the double denial of the possibility of architecture as a self-contained activity and that of man as a being independent of the environment gave rise to the opposite conditions: architecture as a sustainable activity that expressed human experience. According to these ideas, architecture was to orient people in postmodern conditions, uniting them with their sense of self and their identity in certain situations. One of the problems with this approach was that it continued to operate with mechanisms that were at odds between knowledge and craft. Otero-Pailos notes, “[Lethaby] blamed architects for being too intellectual and warned that too much ‘brain work’ would lead to the catastrophic disconnection of architectural design from the work of building and its eventual decline into a self-referential visual game.” [63] He added that this problem was compounded by the mechanization of the construction industry, which lacked a true understanding of manual craft. [63] Indeed, it is important, according to William Richard Lethaby, to prevent precisely this camp of intellectuals from forming theories at the expense of those who worked manually. Consequently, he proposed that all academics and theorists should do manual work as part of their training. He suggested that no one ought to enter intellectual professions—such as stockbroking—without first completing at least a year of manual training. For others, including Members of Parliament, architects, clergy, and teachers, he proposed two years as a demonstration of commitment. Only on such a foundation of practical experience, he suggested, could there be any hope of mastering the machines before they destroy civilization. [63] This idea, that place is the moment where a person can truly experience the object uninfluenced by anything else, was taken from the phenomenological approach, which positioned itself as an alternative to technological society. Phenomenology began with Edmund Husserl at the beginning of the twentieth century, to describe experience as a notion independent of prejudices. It sought to determine things as they appeared, or more precisely, as they manifested themselves to consciousness through experience. Whereas, as for phenomenological architecture, this approach has used the notion of experiencing things as a tool in design, in the post-modern world. Guided by the notions of phenomenology, phenomenological architecture claimed that architecture was the field that dealt with authentic human experience. Otero-Pailos states that architecture according to phenomenologists is best understood “not through abstract mental analytic categories, but through direct experiences of the building, during which one would project oneself fully onto it, especially feelings and emotions, as a way of fully grasping its intentional content.” [63] Robert Vischer's theory, for example, claims that there is a function of harmony between the form of objects and the structures of the senses or the body, which expresses the beauty of the building. [68] Moreover, Ernesto Nathan Rogers mentions that

to be an architect who responds to the needs of society, one must create forms from existing traditions, to add new experiences in harmony with existing ones. [69] To do this, architects, according to him, must be as empathetic as possible, to feel the cultural experiences gathered within the field of construction. He also believed that the history of architecture was in fact reflected by buildings as a carried collective experience and, as such, could only be accessed through experience. [69] Charles Moore confirms this idea when he says that "this search [of poetic images] could not be done in a detached, intellectual way: it was a matter of experiencing buildings directly" [63] According to him, thought was a reduced abstraction of the reality of corporeal experiences.

In addition, other architects of the time shared more or less the same attitude. Norberg-Schulz also believed that architecture was the expression of human experiences. [70] He claimed that diagrams were the link between visuals and texts and this gave him reason to argue in a phenomenological way that practice and theory were inseparable from each other, although with an unclear connection. Unlike others, however, he believed that human experience could be found in nature. He took his argument so far as to believe that, in order to find the history of a place in new projects, designers should not look at the historical buildings that had been built there, but should actually go back to the original source: that of the landscape without buildings. [70]

Phenomenological architects, although they were in favor of the individual values of an individual's experience, were against the statement that experience was entirely individual. For them, sensory experience had common human characteristics, independent of time and space. Consequently, they were the only post-modernist movement that sought to evolve architecture by establishing other modernist ideas. To explain this paradox, Otero-Pailos explains that architectural phenomenologists believed architects should hold commitments beyond the self, seeking a community of shared values and beliefs to ground personal expression. [63] They argued that postwar modernism excluded the essential experiences of their social community and generation. Unlike other postmodern philosophies, phenomenologists did not turn back to history but instead built with the modernist ideals of originality and ahistoricity. Paradoxically, their awareness of modernism's history drove them to search for an ahistorical constant at the core of architectural expression. For them, sensory experience was that timeless constant—a belief that, interestingly, contradicted the inherently historical nature of embodied experience. [63]

To connect modernism with the rest of architecture meant for them to understand a common prelinguistic language, which they considered as the principle on which every building ever was built. Although they followed different paths, the points that connected phenomenological architects together were designing through experience and the use of senses, as well as the exploration of history and the establishment of common theories between phenomenology and different disciplines. Also for phenomenologists, the object

and the subject were no longer separate, but, between them, there was an interaction that represented the values of architecture. Which means that according to them, circumstances become reality when the experience of all the senses comes into play. The key word here is “all” the senses.

A walk in the forest is healing because of the interaction of all the senses at the same time—in Gaston Bachelard’s words, “there is a polyphony of the senses”. [24] The eye in this case cooperates with the body and the other senses. From this comes a greater understanding of reality. It is the task of architecture to be a continuation of nature, in the path to help man find himself as close and as connected to the world as possible. Structural objects are not isolated artifacts.

All structures come from an aesthetic emotion caused by the interaction of the sense of sight with the terrain, which we find it impossible to avoid. However, beyond these optical visual effects, there are other factors, more influenced by feelings. Torroja, for example, says that the feeling we get from the configuration of a beam is better if it has a negative deflection or camber deflection [3], but I would be more reserved and say that at least it should not be bent down; otherwise, the observer would be overcome by an undesirable feeling of fear. This probably happens because we associate the image with the feeling of strength of the material and we are influenced by this. The fact is that the natural deflections of structural elements and their external forms affected by these deformations under the action of loads convey to us an impression that the structure is tired, inadequate, while the opposite of these forms—for example, beams bent from up above—may give us the impression of strength.

The psychological factors, which are difficult to specify, significantly influence the way in which structures are designed. For example, why are the columns of a lamppost larger and stronger by their shape than a flagpole, which, considering the loads, has to support a much larger moment? Logic would say that one structure should be replaced by another, but imagine a flagpole with the structure of a lamp post. Likewise, the blossoms of a cherry will always be gentler than those of an oak or a pine. It is often forgotten that one of the characteristics of beauty is precisely that it does not necessarily follow from logical reasons. There are certainly general rules, but they never manage to turn artistic creation into a system of equations. In such cases, the problem remains undefined. It is not enough and is not a condition, for example, that the shape of a woman fulfills all the rules established for proportions to be beautiful. Similarly, it is not enough for a structural design to be entirely dependent on laws, norms and rules, or to seek to evaluate structures solely by their technical performance. Torroja remarks that the Victory of Samothrace, being carved in stone with wings unsuited to flight, can never literally rise into the air. Yet, “standing there in the Louvre as a ruin, armless, without head, it will always continue to appear to us as the supreme expression of all our dreams of victory and as the predominance of ideal over matter”. [3] He understands the importance of the human-object relationship and the importance of the

sensations that objects convey to humans. For him, the definition of good structural design is expressed in this way: “The best possible rule for the creation of a truly beautiful structure is that the designer shall have a serene and acute artistic sensibility, and a fecund creative imagination, served by the requisite technical skill to understand the purpose and mechanism of its strength behavior.” [3] In the case of structural design, technical issues are very important, but this knowledge and skill often comes at the expense of ignoring cultural and social values. On the other hand, designers who proceed their designs with creative knowledge and skills often do so at the expense of their technical requirements.

The fact that a structure is evaluated throughout its life, not by its implicit characteristics, but by its explicit characteristics, which are perceptible to the user, raises another problem. Its structural potential is invisible, hidden by the project calculations and the qualities of the material used. It is difficult to make progress in terms of the quality of the structure as long as there is no participation on the same level of knowledge by the users, as well as by the designers or contractors. It is precisely in this ideal environment—that of equal knowledge—that structures would be truly honest and only then they would be truly judged for their structural performance, as the engineer alludes to in the university auditoriums. But this is impossible. Kenneth Frampton suggests a solution that unites the experience of the individual with the importance of the technical aspects of construction. He wanted small tectonic details to express the structural logic of an entire building culture. [30] With the theory of Tectonics, Frampton in a way made a vicious circle to return to the principles of the beginning of his career, when he worked on graphic designs of architectural projects and asked himself how, instead of the building, to present an experience that went beyond the building itself, but one that was certainly related to it. Tectonics, in particular, is a good case for this thesis because it carries the values of the post-modern spirit—especially phenomenological principles—and deals specifically with finding architectural cultural values in structures. It also asserted that structural design and architecture in general is influenced by the experience of construction itself. As such, it reinforces the idea that structural design and cultural values are deeply interconnected with each other.



Figure 50 - Tectonic articulations, emergency cabin near Kjeragbolten, Norway (author, 2022)

Without denying the volumetric character of structural form, Tectonics reasserts the importance of construction and structure in space. Architecture is embodied in structural and building form, which is not simply technical but is a potential for expression. Building, according to Frampton, is first and foremost a construction, and then later becomes an abstract discourse of surfaces and volumes. [30] Unlike fine arts, it is both an everyday experience and a representation. The different typologies of form are created by the application of technique and the conditions of the terrain. As a result, Tectonics is astylistic—it favors neither Constructivism nor Deconstructivism—which means that it resists categorization into certain fields. It is neither just art nor just science and, instead, it fits more with the ontological concept of the building as “object” rather than “sign”. [30] This also explains the fact that, despite the efforts of architects to design according to the artistic styles of the time, such as Cubism, Suprematism, Neo-plasticism, etc., these movements failed. They had difficulties becoming an object.

The term “tectonics” is always associated with technology, which makes this notion even more ambiguous. That said, this term can indicate three different things depending on how the construction is expressed:

- (1) The technological object, which is something created to solve a practical problem (for example, a footing that supports a structure and serves no other purpose);
- (2) the scenographic object, which is intended to look like a structure or a building or something related to construction, but is in fact of another nature (for example, a fake column on a facade) and
- (3) the tectonic object, which is a special category that exhibits two modes. These modes, according to Frampton, are ontological and representational tectonics. [71] The first involves a building element that has been shaped in such a way as to express its static role and cultural status. In the second mode, the element is still building, but it is hidden, and the designer indicates its presence through some representational means. An example in this case might be a beam hidden within a wall, but with a change in the wall's pattern at the point where it meets the beam.

All three of these cases vary between “structure as technical” and “structure as symbolic”. On the one hand, we have, for example, the Cyclopean structural system at Mycenae, which seems to rise up out of the ground. On the other hand, we have the Crystal Palace, a structural system that seems to defy gravity. Since most works are somewhere between these two extremes, we can say that the poetry of the building arises partly from the inflection and positioning of the tectonic object. As a result, the ground below is raised in some way and becomes an arch or vault, or alternatively, it is pulled back to support the wall or raised higher again to become a podium.

Frampton also acknowledges the value of ornament in structure. [30] He explains that, contrary to Perret's slogan “There is no detail in the construction”, Gregotti insists that detailing should never be dismissed as a mere technical necessity. Instead, the tectonic quality of architecture arises from its ability to express both poetic and cognitive dimensions. Achieving this requires mediating between technology as a productive process and craft as an older yet renewable practice that reconciles diverse modes of making and layers of intention. In this sense, the tectonic resists the contemporary tendency to downplay detailing in favor of emphasizing only the overall image. [30] However, for Frampton, there is a line that should not be crossed. He is against unnecessary figures. He argues that, since buildings have the responsibility to live in a place for a long time, they should look like they have always been there. [30]

The values of a building for him are not revealed by any of its structural elements, nor by its overall form, but by the way, in which the structural elements fit together. Systems like The Balloon Frame, for example, has a structure that can be articulated very easily and as a result, its form can be adapted depending on the circumstances. However, other systems like that of concrete, despite their benefits in durability and stiffness, have difficulty in articulation.

“Aesthetically concrete has neither song nor any story. Nor is it easy to see in this conglomerate, in this mud pie, a high aesthetic property, because in itself it is amalgam, aggregate, compound. And cement, the binding medium, is characterless”, [30] says Frampton. Auguste Perret was among the first to try to articulate concrete in construction. In a long passage dedicated to him, Peter Collins notes that Perret pioneered the use of bouchardage or bush hammering, a masonry technique traditionally used to clean roughly quarried stone, adapting it to expose the surface of rough concrete. [72] Whether or not he was the first to do so is less important than what it signified: for Perret, revealing the qualities of the structural material was just as essential as expressing the construction system itself. Far from lacking attention to detail, he became almost obsessive about it, achieving refined profiles through variations in the timber formwork and subtle coloration by selecting aggregates of different sizes and hues. [30] And indeed, the construction technique for Perret was the bread and butter of architecture. As such, he states: “Technique, permanent homage to nature, essential food for the imagination, authentic source of inspiration, the prayer of everything that is most efficacious, maternal language of every creator, technique, spoken poetically leads us to architecture.” [30]

For him, if architecture is the art that organizes spaces, then construction is the means by which architecture expresses its values. According to him, construction was the architect's native language and the architect thinks and speaks only through construction. As per the skeletal system, like Torroja, even Perret compares it to the human skeleton. As such, the skeleton for him should be rhythmic, balanced and symmetrical in order to support organs with various shapes and functions. Through Perret's vision and words, Frampton argues for his theory of Tectonics and especially the importance of craftsmanship. In Frampton's book, *Studies in Tectonics Culture*, he quotes an interesting conversation between Perret and Denis Honegger, where Perret is said to have remarked: “We no longer know the language of stone. Everything that we make in this material today is only a lie and a trick. We no longer know how to raise a vault and we anchor our stones with iron cramps.” [30] He criticized modern practice for relying on hidden supports of iron or reinforced concrete, and he declared, “I challenge any contemporary architect, no matter who, to reconstruct the nave of Bourges with the same conscience and feeling for material.” [30]

Tectonics also values the durability of structural systems, since for this theory; the ability of the building to resist time is precious. This feature is especially fulfilled by the structure of the building, since, according to Perret, “It is the framework that furnishes the building with elements and forms imposed by permanent conditions and that, subject to nature, attached to the past, establishes the durability of the work.” [30] This appreciation of construction meant that even though he had almost constant control over the architectural work throughout his career, Perret always called himself a constructor, rather than an architect. The notions of Tectonics also find itself partly in Modernism, which gives Frampton one more reason to argue that Modernism is connected to other movements in the continuum of

time and that the phenomenological spirit was outside of time, affecting human activities throughout the history of its existence. Defending his thesis, Frampton highlights several ways in which phenomenology resonates with Perret's work. He notes that Perret consistently pursued a tectonic line characterized by: (1) the articulation of the structural skeleton as a fundamental ordering principle; (2) a focus on the joint as a techno-poetic center; (3) the reinterpretation of traditional elements to maintain cultural continuity; (4) an emphasis on key features such as the cornice, French window, and helical staircase, which he saw as emblematic of a tectonic civilization; and (5) a commitment to rationality as a transferable method, aimed at sustaining and advancing a normative culture. [30]

Indeed, other architects of the Modernist movement carried aspects of Tectonics in their works. The Barcelona Pavilion has tectonic values through eight cruciform columns that stand free, dividing the space into frames that bypass these elements (fig.51).



Figure 51 - Barcelona Pavilion, Mies van der Rohe (author, 2025)

Mies van der Rohe also mentions the importance of the role of the structure and the expression of architectural values through it. In an interview with Peter Carter, he recalls Berlage as a man of great seriousness who refused anything inauthentic, insisting that nothing should be built unless it was clearly constructed. Berlage embodied this principle in his Amsterdam Beurs, a building with a medieval character without imitating the medieval, using brick as it had once been used. From this, Mies van der Rohe drew the lesson that clarity of construction must be taken as a fundamental principle. Yet he acknowledges that, while it is easy to speak of such clarity, it is far more difficult to uphold it consistently and then raise it to the level of a true structure. [30]

Kahn, on the other hand, chose not to use reinforced concrete in the beginning of his career because of the structural elegance offered by the steel structural system. For him, the former carried several disadvantages in terms of the experience it offered. [73] First, the idea that to build a concrete structure one had to use another temporary supporting structure did not sit well with Kahn. Second, reinforced concrete represented a “false” material in the sense that it apparently worked in compression, but inside it contained a material that made it work well in tension as well. The problem was that the architecture that Kahn wanted was impossible because of the limited possibilities offered by tectonics. “I dream of space full of wonder. Spaces that rise and envelop flowingly without beginning, without end, of a jointless material white and gold. When I place the first line on paper to capture the dream, the dream becomes less.” [73], he said. What he actually wanted was a continuity of force paths, as in the case of the vault, but steel construction did not offer this. Concrete, on the other hand, did not have the brilliance and clarity that Kahn wanted. Furthermore, reinforced concrete construction could not be built continuously since, according to him, the steel reinforcements were not visible in the final form of the structure. Third, the fact that it was a casting process and not an assembly contradicted their principles of structural rationalism. All these values, regardless of purpose, had their origin in structure and as such, according Frampton, carry the stamp of Tectonics. [30]

Aris Konstantinidis also argues that architecture cannot exist without construction. [74] For him, construction is the embodiment of material and its proper use. Consequently, each material imposes its own logic: stone requires a specific method, steel another, concrete likewise. That said, architecture can be achieved with any material as long as they are applied in respect of their characteristics. Also in a place where there is only one type of material, the designer's task is to build with that material. With that being said, the values of design do not lie in the invention of arbitrary forms but in what he calls the “spirit of construction”, united with flexibility and responsibility. [30] In his view, another decisive role is played by the conditions of the terrain such as climate, topography, type of soil and available materials. At the same time, Konstantinidis criticizes the notion of efficiency and scientific rationality in architecture. For him, architecture should have a sentimental and imaginative dimension. If this is ignored, it risks becoming stagnant and mechanical. He states that materials should

be selected not only for reasons of economy and scientific rationale but also with creativity and emotional freedom. For him, architecture ultimately transcends mere functionality, rising above logic and detached calculation. [30]

Despite the concept of tectonics over mere calculations, it is a fact that structural designers in the era of modernism, influenced by computational methods, created forms that expressed the values of Tectonics. Of the most prominent structural designers of that time, Pier Luigi Nervi, writes:

The experience acquired in almost fifty years of direct contact with activities in various fields of design and construction have led me to an optimistic conclusion: the unlimited possibilities of design offered by scientific theories of construction, the executions made possible by new building materials and current techniques, and the architectural themes growing ever greater and more complex as dictated by our social and economic developments, open horizons of unprecedented possibilities of construction as compared to what humanity has achieved from prehistoric times to the present.

Nevertheless these marvelous possibilities cannot be fully developed if the three fundamental factors of any construction—the architectural concept, the structural analysis and the correct solution to the problems of execution—do not proceed in close collaboration having as its aim the sole and unique goal of arriving at a proposed result combining functionality, solidity, and beauty. (Nervi, 1961) [75]

Thus, Frampton shows that Tectonics brings together all architectural movements and, in this way, is a notion independent of time. For him, regardless of time, one thing does not change: How the presentation and re-presentation of the building as a constructed thing has proven to be the essence of the phenomenological presence of an architectural work and its form embodiment. It is precisely this observation that, according to him, places architecture in a cultural tradition that is collective rather than individual, and places architecture in a certain time or with certain methodologies that depend on the history of the material.

He argues that the tectonic has always stood against the fungibility of the world, maintaining a tradition that simultaneously strives to generate the new while reinterpreting the old. Despite the personal traits of individual architects, its very nature is anti-individualistic, since—unlike painting or sculpture—it is not grounded in the subjective production of images. [30]

Andrew Vernooy argues that the tectonic integrity of architecture has been weakened in contemporary culture, especially after the 2000s. [76] In contrast to modernism, which used the structural system as a basis for synthesizing structural form, the demands of today have diminished this aspect of design. As a result, architecture has become even more separated from structure. The reasons he mentions for this diminution are the construction of multi-layered external walls, many of which are industrially based. But even more important is the

reduction of the meaning of the material from an embodied reality to an image. For Vernooy, this development has its roots in media culture and imagery, where symbolic allusions are accepted instead of material permanence. [76] For example, it is no longer considered necessary to build with real stone material in order to achieve durability. Developers are content with using stone tiles as a covering to appear to achieve durability. Therefore, the characteristics of the material in this case are used only to present its symbolic values rather than to genuinely express it. This has resulted in the weakening of the role of architecture in situating the built form within the cultural and physical context. Another problem of the image to the detriment of the notion of tectonics is that architecture is not treated as grounding spatial experience and is increasingly finding a place in images and mere shapes. As a result, building and construction no longer have architectural value. For Vernooy, this is a signal that foreshadows the loss of tectonic authenticity and the return of architecture from a building art to an image economy. [76]

The problem with Frampton's Tectonics was that it could not get rid of time. Indeed, in an exposition of the tyranny of time, Otero-Pailos comments on Frampton's work this way: "In the new neomodernist contexts, Frampton's figure of the master-mason became the model for architects interested in controlling construction costs through rapid prototyping and in eliminating the skilled craftsmen that Frampton cared so much about." [63]

Phenomenological reduction signaled an important shift from experience to intuition. To sense something is to understand it directly, without analyzing or reasoning. This focus on intuition was the main reason for defining Frampton's work as pure phenomenology, in the sense that it dealt with the realm of pure consciousness. In the context of design, intuition served as an apotropaic concept, meaning that it was assumed that knowledge about buildings could only be acquired through rational methods and the preservation of a subjective kernel.

Structures and architecture have another function, that of time guider:

The most essential auditory experience created by architecture is tranquility. Architecture presents the drama of construction silenced into matter, space and light. Ultimately, architecture is the art of petrified silence. When the clutter of construction work ceases, and the shouting of workers dies away, a building becomes a museum of waiting, patient silence. In Egyptian temples, we encounter the silence that surrounded the pharaohs, in the silence of the Gothic cathedral we are reminded of the last dying note of a Gregorian chant, and the echo of Roman footsteps has just faded away from the walls of the Pantheon. Old houses take us back to the slow time and silence of the past. The silence of architecture is a responsive, remembering silence. A powerful architectural experience silences all external noise; it focuses our attention on our very existence, and as with all art, it makes us aware of our fundamental solitude. (Pallasmaa, 1996) [24]

Pallasmaa is also a skeptic of the modern spirit, as he too has understood that architecture cannot be entirely functional without losing its existentially mediating function. [24] That is, a structure cannot be entirely clear and directed towards function and rational motives, but must also carry its own unfathomable secret and mystery in order to stimulate our imagination and emotions. Structural elements are not image units, nor mathematical units, but contain confrontations that interact with memory and more. “In such memory, the past is embodied in actions. Rather than being contained separately somewhere in the mind or brain, it is actively an ingredient in the very bodily movements that accomplish a particular action”, [24] writes Edward Casey. Seen from this perspective, experience cannot be found entirely in man, nor in structure or object, but our conscientiousness is in fact somewhere in between. This will be discussed at length in Chapter 4.

The experience that the house offers is structured by activities such as eating, cooking, talking, reading, sleeping, etc., and not by visual elements. As such, the building collides with us. It brings us closer, gives us something and hides other things, depending on the situation of our body. It does not control, but it certainly encourages, influences, directs or organizes a certain behavior and certain movements. The building is not an objective in itself. It must divide, articulate, structure, connect, unite, stop, etc. It is all these activities that make me believe that human experiences and the main purposes of structures all take verbal forms, not nouns. That said, building forms should be designed starting from the body’s encounter with the object and then dealing with the external appearance of a facade—or an element. The act of entering through the door is more important than its appearance. Looking through the window is more important than the window itself as an object. Conversely, feeling the vibrations of the slab is more problematic than the geometry of the slab section. “Architectural space is lived space rather than physical space, and lived space always transcends geometry and measurability.” [24], Pallasmaa.

Seen from this perspective, it is in fact the human body the privileged thing for which we should design. First, we should design for the biological aspect of the body (for its proportions and senses) and, second, we should design for the body in the social sense (the social impact of spaces). What is interesting about this postmodern spirit is that they deny their positioning on a common ground, except that they all support the above arguments. For them, it is not a matter of defending design as “anything goes”, but of suggesting that spaces, objects and structures be considered as social agents, accepted with all the contradictions and ambiguity that this notion offers.

3.3 The Spirit of the Age: The Case of Tectonism

The digital revolution has brought a series of powerful new tools to architecture and has also enabled new tools for structural engineering to analyze and calculate structures towards parametric variety, written-based instructions with the so-called AI, as well as the production of images through the so-called AI.

We are living in a complex and dynamic world where social institutions and the definitions for them proliferate, mix and seem to merge with each other, creating a social texture that is gradually transforming. As a result, stereotypes that were previously stable are breaking down and previously well-established hierarchies are now being questioned. The modern design approach has now given way to the social design approach of the post-modern.

The new post-modern approach has its own catalyst, which is the digital revolution and the advancement of computers and social networks. The aspects of construction have not been left untouched by this hurricane. Society requires building designers to reform their program to systematize the values dictated by society. The new condition, for example, as we have already seen, is that new construction projects must be characterized by both novelty and complexity. Routine solutions and solutions independent of the situation have begun to be judged with a more negative connotation because they are defined as belonging to the realm of computers.

The new spirit calls for closer collaboration among developers, engineers, and architects, blurring their traditional boundaries, challenging the self-contained autonomy of distinct systems like the economic, political, or artistic. Charles Jencks also reinforce this assumption: “Whenever there is a revolution, or fast change, in architecture, professional barriers break down as specialists exchange roles. Architects become sculptors, engineers become designers, artists turn into architects, and all these job descriptions become fuzzy.” [19] He points out that this dynamic occurred during the Early Renaissance with Ghiberti and Brunelleschi, who shifted from goldsmith to sculptor and from artist to architect, as well as repeatedly throughout the nineteenth and twentieth centuries with figures like Eiffel, Tatlin, Duchamp, and Le Corbusier. For Jencks, the willingness of professionals to cross boundaries is a key measure of the avant-garde; without such role-shifting, there can be no genuine breaking of barriers or radical creativity. [19]

It is used as an argument that disciplines are merging because an architect is learning to code or an engineer is learning to code. It may seem at first glance as if computer science is merging with structural design, but we must remember that John von Neumann, for example, was an engineer and co-creator of the modern digital computer. In the beginning of modernism, computer science was not a separate activity. It was born initially from the need of many professions to acquire computational methods to help them in their activities. The

fact that computer science has now become a real field of specialization and then we are told that we are merging with this field while computational methods were born and have always developed from the need of other activities such as structural design—making black box programs, exploring solutions, solving non-linear equations, etc.—shows quite the opposite. It shows that we are increasingly becoming more and more separated. To the extent that we are now, we are calling self-referential disciplines even things that have grown during modernism and developed together with structural designers during modernism. Therefore, I do not think that the self-referentiality of professions is weakened. On the contrary, I think we are further apart than ever before.

Patrik Schumacher outlines the relationship between architecture and engineering by noting that architecture addresses the built environment's social performance, while engineering ensures its technical performance. [11] Since technical soundness is a prerequisite for social impact, engineering could be seen as primary. Yet because social performance is the ultimate aim, architecture might also be regarded as primary. He concludes that the relationship cannot be reduced to a strict hierarchy but is one of mutual dependence and dialectical progression. Architectural goals must be framed within the technical limits set by engineering, while engineering research broadens the range of possibilities that shape design. At the same time, engineering advances do not always move in desirable directions, and architectural innovation itself can be stimulated by breakthroughs in engineering. [11]

Complex forms can now be analyzed with the advancement of technology, questioning the need for existing structural formalisms. This is significant because it questions one of the core principles of traditional structural design—the tendency to normalize forms based on their performance. Moreover, it is no longer enough for the structure to be safe, and it is not enough for the form of the structure to perform well against traditionally accepted aspects of design values—such as economic efficiency, energy performance, construction time, etc. In the case of traditional structures, the ability to analyze and calculate the behavior of the structure depends mainly on the purity of the structural system and the severing of all unnecessary connections. However, the types of structural elements that are completely clear—such as beams, columns or arches—are increasingly being used less and less by structural designers.

This phenomenon has also come about due to structural analysis techniques, such as Finite Element Analysis, which, due to the great computational power required, have only now begun to be used on a large scale with the advancement of computer computational power. According to Schumacher and some other contemporary structural designers, this practical possibility alone has brought about a change in the ontological aspect of structures: Structural elements are no longer the focus of calculations; instead, the emphasis has shifted to the finite element. [11] In contrast to the transformation of structural form into clear structural elements, which occurred in modernism, the finite elements did not come from the

influence of architecture, but from the science of structures and mechanics in combination with the possibilities offered by new computers. The effect of this change, initiated by scientific achievements, has already made a lot of progress into the culture of construction, specifically in the design of the overall form of the building and the form of structures. An example of this case is Parametricism. Parametricism as a design style is the composition of forms by first defining all the parameters on which one wants the form to depend. Once one has finished compiling the parameters, their relationships, and defining a clear path to the product—which is actually the definition of an algorithm—the design becomes a matter of exploration between the limited values of the parameters. To show the connection between programming, structural engineering, and their influence on the forms of buildings and on the cultural aspects of construction, Schumacher has coined the term “Tectonism”. [11] Tectonism, as we will see below, is a methodology but it is also a style. An example of Tectonism is form-finding, which made it possible to produce the structural forms of the Munich Olympic Stadium. Another example are the generative structural forms that result from the application of optimization methods to achieve a certain performance objective.

With that in mind, Schumacher claims that Tectonism is the only style that has derived from the latest achievements of science, and not from social aspects. [11] He cites Zaha Hadid Architects’ *Phaeno Science Museum* in Wolfsburg (fig.52) as an early case where structural systems evolve alongside architectural form. The building combines spanning, cantilevering, and vaulting within a variable waffle slab, while cones merge into it rather than acting as isolated supports. Above, a differentiated space frame spans in two directions, giving each cell a unique size. Such complexity, he argues, can only be managed through computational methods, both for structural analysis and for coordinating geometry and fabrication. [11]

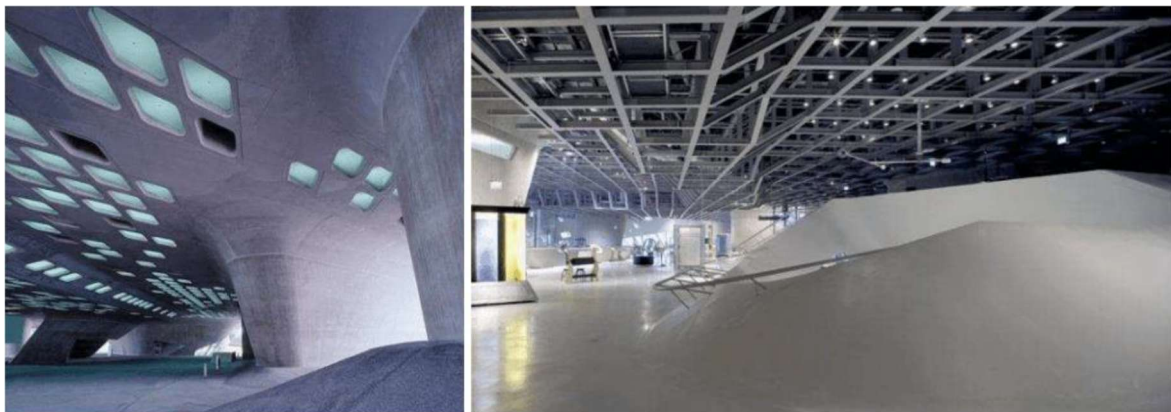


Figure 52 - Zaha Hadid Architects, *Phaeno Science Centre*, Wolfsburg, Germany 2000-2005
(adapted from Schumacher, 2022, p.42)

For Schumacher, it is clear that the parametric design style is congenial to the latest advances in engineering and the only style that fully utilizes the new engineering potential. [11] As a sub-style of Parametricism, he states that Tectonism carries the superior social functionality of Parametricism while respecting the goals and challenges of the social conditions of the

zeitgeist. This superiority, according to Schumacher, comes from the adaptability of Parametricism. The problems that this style seeks to solve can be complex, irregular, overlapping forms, gradual transformations, and so on. This, according to Schumacher, can be called spatial topology in the service of social topology. Then he claims that Parametricism has the potential to perform all these tasks and also maintain its authenticity in the face of all these complexities. Tectonism, according to him, can do even more than that. It can also fulfill the above tasks, as well as achieve certain optimization criteria such as structural performance, energy performance, etc. [11]

Parametricism allows morphologies to adapt and interact with each other, while Tectonism imposes other conditions to achieve better performance of the forms. According to contemporary designers, if we refer to the historical progression of architecture over the last 200 years, whenever more requirements and varieties had to be considered, this was done only by reducing the rules. [11] Likewise, in the case of structures, more freedom meant fewer rules. However, according to Schumacher, Tectonism, unlike other methods, offers freedom in design by increasing the order. [11]

Patrik Schumacher: “Parametricism, and by extension Tectonism, is architecture’s answer to the challenges and opportunities of the (post-Fordist) information age, just as modernism was architecture’s answer to the (Fordist) mechanical age.” [11]

Then he continues by implying that the increase in the degrees of freedom of design was made possible by the multiplication of the possibilities of structural forms. [11] This increase in design freedom and in the variety of forms was the main criterion in the pursuit of society’s values by design. Just as the movement from classical architecture to modernism, the transformation from modernism to post-modernism in architectural design—such as the Deconstructivist style—was only possible thanks to the increase in freedom and possibilities of structural forms that could be designed. This, as we saw in the previous subsections, was made possible by removing some of the formal rules. From the transition from classical to modern architecture, certain rules were removed, for example, it was not required to make symmetrical buildings anymore. From the transition from Modernism to Post-modernism and Deconstructivism, the requirements of orthogonality, clear separation of elements and balanced asymmetry were removed. [11]

In his point of view, the rule has always been inversely proportional to the freedom of design until the birth of the Parametric style and then Tectonism. [11] According to him, tectonism in particular does both; it manages to give freedom of design, but also to regulate the form of the structure according to predetermined conditions. [11] As such, this design method claims to be expansive in accommodating the contingencies of post-modern society, and at the same time not to reject the formal rules established in other periods, which even the post-modern spirit cannot reject—such as bearing capacity, allowed deflections, seismic

performance, etc. According to Schumacher, the principles that Tectonism uses are diverse and open-ended, enabling the flexibility necessary to accommodate contradictory values in design. This allows designers to provide different solutions and maintain the identity of individual projects, thus avoiding the general formalisms that were abandoned with the decline of Modernism. Tectonism as a methodology has its roots in computer logic, especially in optimization methods, which will be discussed in Chapter 5. This methodology can be used for all phases of design and especially in the pre-design stage, since achieving performance objectives in buildings is directly related to their structural form.

Schumacher explains that tectonism broadens architecture's repertoire of problem-solving and articulation, drawing on coherent logics from multiple engineering fields—structural, environmental, and material fabrication. However, these added resources contribute less to unlimited freedom for the designer and more to architecture's capacity for order and coherence. This expansion therefore comes with new constraints, which is why, he notes, the relevant part of the graph (fig.53) trends more upward (toward order) than forward (toward freedom). Still, he acknowledges that the shift from Swarmism to Tectonism brings a net increase in design options and choices. [11]

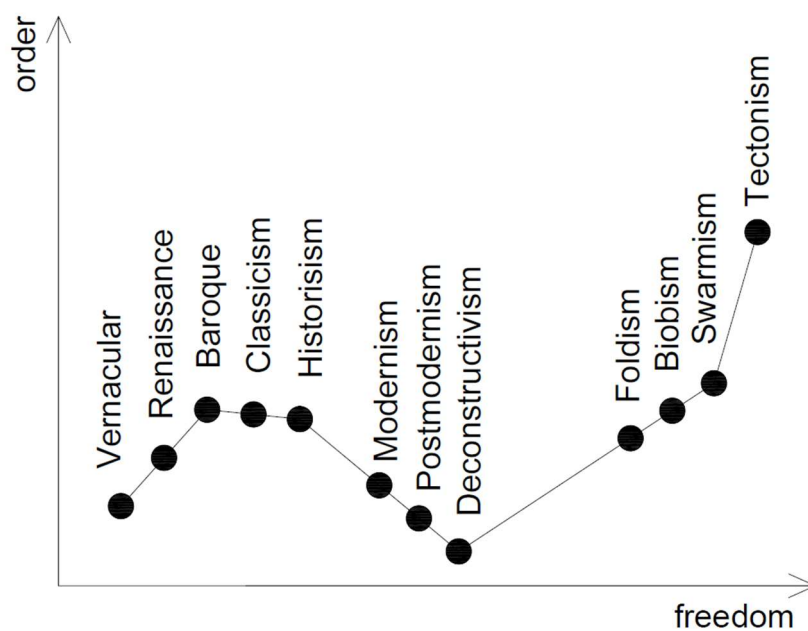


Figure 53 - Order/freedom style progression graph (adapted from Schumacher, 2022, p.152)

However, as we have seen so far, it is not true that the post-modern design has bargained freedom by reducing rules. In fact, as we have already discussed, in every period, designers have never stopped seeking both—freedom and order—because to give meaning to design is to break the order. That means that order and freedom were pivotal in every design in every era.

The Tectonism style makes computational logic speak, through a design code written by the designer. Once the code is written, the computer can explore a variety of shapes—one for each value of each set of values of a parameter, combined with the other set of values of other parameters. As you may imagine—and this will be seen later in Chapter 5—the variants of shapes under study are extremely large and can grow exponentially with the addition of parameters. This way of design guides the designer and suggests to them the best versions, which the designer has the option of choosing between them. The assumption from contemporary structural designers is that these generated shapes do not only reflect structural performance, but can also reflect social values. The problem is that the scripts that enable the generation of the form operate with computational objectives and these objectives must be measurable.

Tectonism as a style, according to Schumacher, has the ambition to reveal, rather than cover or hide, the structure. [11] Structure is generated primarily in the form of patterns. These patterns, which can be structural elements or structural details, become instruments of articulation and experience—which also explains the definition of the style of Tectonism. Structure in this case has a double life, serving both the technical-functional side and the cognitive-social side. This style also accepts ornament. In Schumacher’s words, throughout architectural history, elements originally tied to technical functions have often been reinterpreted as aspects of articulation or ornament. He stresses that ornament should not be seen as opposed to performance but rather as a distinct form of performance—one that communicates meaning. In this way, a morphology designed for technical efficiency also takes on an expressive, communicative role. [11]



Figure 54 - Monasterio de San Juan de los Reyes, Toledo, Spain. Tectonic articulation, photograph by Megi Tafaj, 2024, used with permission

Even Schumacher, who is a contemporary designer, acknowledges that integrating articulations of morphology as a consequence of technical requirements is always more elegant than attempting to fight or counteract them by hiding or fading them. [11] The latter would require additional articulations. The general accepted assumption by the contemporary designers regarding tectonic articulations is that they are generally economical forms, as well as offer a high level of reliability in terms of structural safety. Such structures offer this level of safety to observers because the morphological indicator is also an index of the construction and not an arbitrary symbol such as a non-tectonic ornament. Therefore, in the words of Charles Peirce, “tectonic articulation transforms ‘indexical signs’ into ‘symbolic signs’”. [11] This process does not limit designers because they have the freedom to choose which structural detail to articulate. Frampton's theory of Tectonics, in fact, is largely supported by the technological achievements of the time. On the other hand, the transformation from Tectonics to Tectonism—as an architectural style—has only been possible thanks to technology. With the development of new computational tools in both the field of architecture and the field of engineering, the possibility of articulating structural elements has increased even more. Their articulation suits the structure generated from the use of optimization methods. In fact, computer-generated patterns itself actually promote their articulation. In addition, the more complex a structure is, the more possibilities it has to articulate its elements. Also, the articulations of the structure do not have to be only for the aesthetic aspect. In the realm of structural design as a human activity, the articulations of the structure can also be regarding environmental or social or economic values or all combined. Tectonism as a methodology allows to overlap several objectives with each other and seek a form that respects all of those objectives.

Frank Gehry's architectural works (fig. 55), despite the misconception of some critics such as Antoine Picon that they are indicative of the crisis of Tectonics, in fact carry the values of material and structure. This is because Gehry initially generated the form thanks to physical models that initially explored the spatial and material dimensions of the structures in reality. These models contained materials similar to those of the structures to be produced. Only after this study was done and the spatial requirements were satisfied, the model was translated into simulation by software and further transformations occurred within a domain of certain spatial tolerances. This methodology, more than indicating the crisis of Tectonics, according to Daniel Cardoso Llach, highlighted the crisis of 20th century architecture. [77] Fundamentally, Gehry's work can be considered "Tectonism" due to the fact that significant transformations of structural form were made possible only by the use of the computer. The integration of computational design and optimization methods that was used in the early stages of simulation has led the design towards rationalization.



*Figure 55 – Partial views of the Walt Disney Concert Hall in Los Angeles, designed by Frank Gehry
(adapted from Llach, 2015, p.96)*

Despite the increase in the use of technology in all design processes, contemporary theories discourage product automation. The post-industrial period is characterized, among other things, according to Malcolm McCullough, by a desire to participate in design processes. [78] Designers do not consider themselves “customers” of software, but rather seek to be participants in something, however humble it may be. This has led contemporary structural design methodologies to be directed towards the need to do work as efficiently as possible, rather than automating efficient products. As a result, digital design is more concerned with “what you will do with technology” than with “what technology alone can do. [78]

Another example of Tectonism is in the structures of contemporary towers. According to the traditional modern approach, the structure of the towers was assumed to be a single, uniform system that was selected according to the height/slenderness ratio (fig.56). If, for example, this ratio was small, the stability of the tower could be ensured with a frame without core or bracings. Then, as the ratio increased, it would be necessary to use a core. A larger ratio meant a bracing system, and an even larger ratio meant a structural shell. This rational methodology seems to belong to a bygone era. At that time, it was not possible to calculate, analyze, or even build complex high structures, forcing designers to come up with uneconomical forms, but simple enough to ensure the conditions of load-bearing capacity and stability. Today, unlike before, thanks to FEA methods and optimization methods, as well as machine learning and the computational power of new computers, it has become possible for the structure of the tower to be divided into partial force-transferring structures.

For example, a tower can now consist of three different structures, which transfer forces to each other without the need for a continuity of elements. Uniformity is neither a desired value nor a condition for the design of these towers. The following diagram (fig.56) describes the modernist approach to the structural design of towers, as well as the approaches of the Tectonism style. The possibility offered by the later to optimize the topology along the vertical axis increases irrationality but offers more opportunities to achieve higher performance.

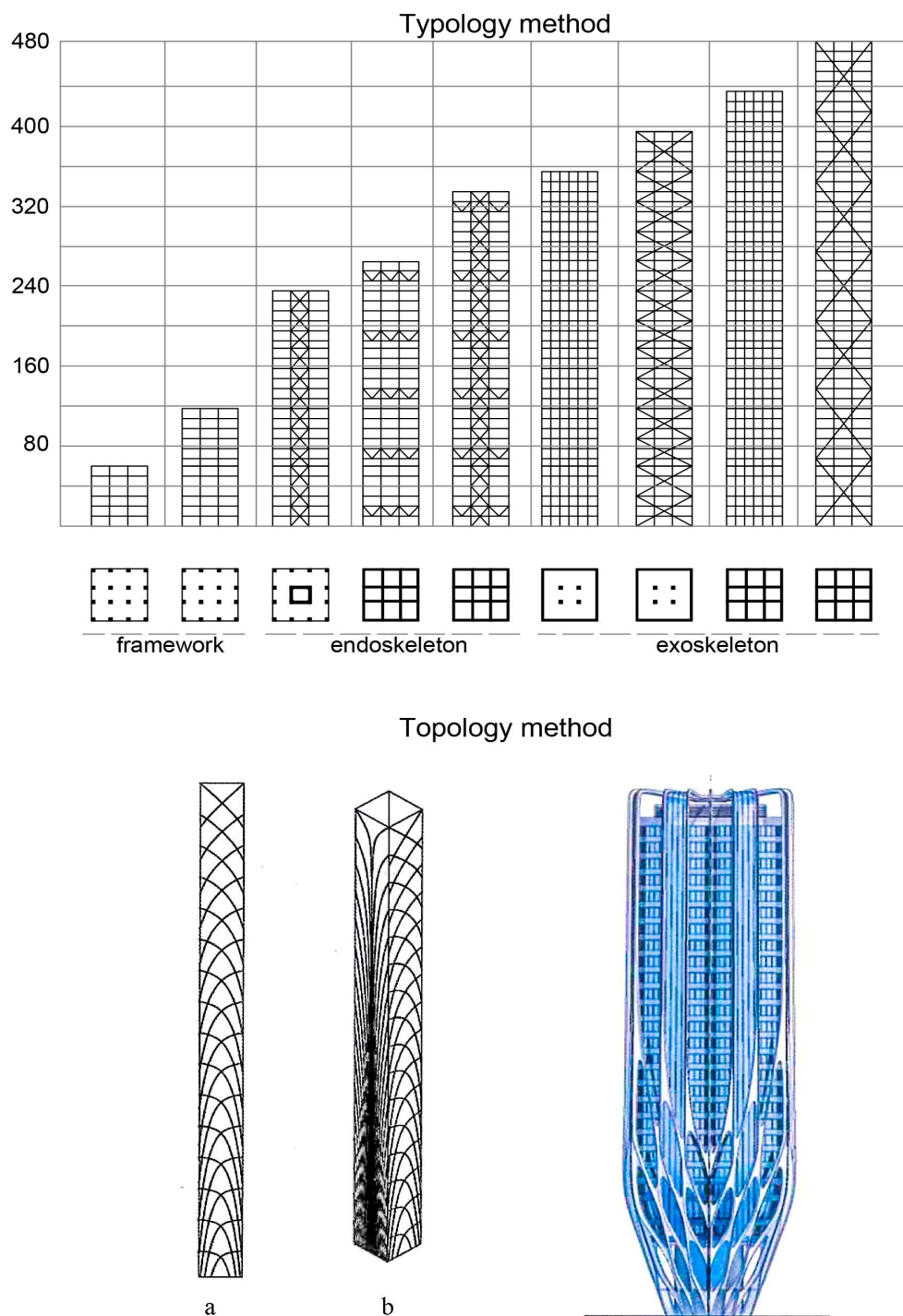


Figure 56 - Diagram of tower structures typologies and topologies (adapted from Schumacher, 2022, p.44-45)

An example that represents the computational era is the Pavilion for Beijing Biennale from Zaha Hadid Architects. This project (fig.57) is composed of three hyper shells—which have been Felix Candela’s signature elements. These shell shapes were translated as layered grid shells, meaning that the gridlines are configured taking into account the computed principal stress lines. The stress densities were roughly translated into a number of grid-line layers. Then, differential colors were added to the system.

As for the future, as computational design tools and AI become more widely used, they will offer the opportunity to explore even more structural forms and achieve building values while at the same time meeting the design requirements. As a result, the designer can explore forms and then decides to choose one, which is supposed to contain the values of the spirit of the time, achieve performance objectives, do this and more.

The greatest advantage of computational design is not based on CAD systems, but in the possibility of designers to interconnect different generative systems with each other, which are transformed into generic coding systems, capable of manifesting their logic in parameters and workflows within an algorithm. Since this generative system allows the creativity of the structural designer to reformulate forms, or configurational systems depending on other factors, this has led to the benefit of new forms that reflect the interconnection of values of different fields. This approach is closely related to the way systems in nature are organized. Visually, the patterns that flocks of birds create when they move in the sky in search of food are very similar, for example, to the way some computational optimization methods search for the best solution for a structural form. Again, these patterns occur in the process of designing the structure, not in the structure itself. But since the process affects the product, there are also cases where the patterns of nature are directly reflected in the form of the structure, thanks to this use of computational design methods for their design. Form-finding is a classic example, where structures take the form of minimal surfaces, which are found in nature, for example in soap bubbles.

What Schumacher and others want to express is that the spirit of the time—the zeitgeist—and specifically the rise of computers in the way of thinking and in everyday culture, have brought new ways of articulating structural forms. Today's avant-garde designers use computational tools to manage the complexity of natural systems and the demands imposed by society. It is precisely this tool that allows you to manage all that complexity of requirements and objectives, and this is what has made design inseparable from the computer.

3.4 Embracing Cultural Norms

Structural Design has lost its meaning: the fact that “engineering” or “engineer” is mentioned dozens of times in Le Corbusier’s book, *Toward an Architecture*, for dozens of different concepts of architecture shows the importance that engineering achievements had for the rise of Modernism. Since then, architecture has developed and moved little by little from an activity to solve purely functional problems, to an activity to solve problems of form. However, Structural Design, which carries the problems of structures and the problems of construction, never recovered from the modern project paradigm. It is still studied today mainly by structural engineers, who refuse to face the problems of form, or even functional problems. Insofar, the school of structural engineering teaches how to face only the problems of the exact science of structures, as if structures were left untouched by the tyranny of life. Sullivan’s famous expression “Form follows function” is never mentioned for structures. There was never “statics follows function” in structural design even though structural designers are concerned with the same problems that an architect is concerned with; the environment, sustainability, material, mass-production, composition, form etc. Structural design vows to deal only with the statics of structures (or dynamics, in seismic regions), but you don’t have to look very hard to find that there is just as much work in structural design that deals with economic and social problems. Not only that, but these values are what actually guide structural design, even though their importance is rarely mentioned in their own merit. This is because, as long as structural designers deny their social values, they will be imposed by other forces.

Otero-Pailos says: “For a building to appear contemporary to an architect it must respond to what is current and relevant to his or her generation.” [63] He also states that what is current is what every designer should consider as good. Such things are the customs inherited from the dispositions of previous generations which every designer must consider before designing (whether he decides to use them or not is another matter). The spirit of the time is manifested in the list of buildings, ideas, regulations, practices that all together form the cultural order of the design discipline. What is current is also very important because it is the community of the value system within which structural design must seek its values. Otero-Pailos said, “In intellectual terms, to dominate the struggle is to be recognized as being more influential than the rest, as having the authority to define architecture.” [63] Which means that the structures we see around us are important indicators of the structural values that dominate society today. But the doubts in this case are whether structural designers will ever be able to define their own values, or will they continue to carry the values of others under the excuse that they are literally making structures and that, according to them, is enough. I have already shown the dangers that come from the second approach.

The other problem is that, seeing the trajectory of the transformation of the social spirit over time, an accurate prediction can never be made of what culture will be like in the future and

how the structural design “game” will change. Therefore, if cultural norms dictate anything, it is to always leave room for contingency in structural design, regardless of the rules that it implies. For example, the cultural stigma that has accompanied different materials over time has changed their use in interesting ways. Thatch, for example, was once the cheapest and least preferred material for roofing systems, so it was rejected by all but the poorest countries, which used it massively, even for objects of worship, such as churches. During the eighteenth century, as parishes became wealthier, interventions were undertaken that replaced thatch with tiles or slates. Since the costs often exceeded expectations, it was decided that the thatch material should be left at least for facades that were not visible to passers-by. Today, however, it is quite the opposite: thatch roofs are considered expensive and the asset of wealthy families.

Giedion explains the difference between repetition and reproduction of cultural values in architecture, which is shown below. Of course, as long as we are talking about aspects of cultural values, we must judge the writing from his point of view and aware that he was situated in the period of his time and his place—which Till considers it the golden age of Modernism. [8]

Today’s architecture approaches sculpture and sculpture approaches architecture. Today we have become sensitive again to the spatial powers of volumes, awakening to an emotional affinity with the earliest origins of architecture. We understand again that volumes affect space just as an enclosure shapes an interior space. This is one of the reasons why buildings like the Tokyo Festival Hall and the Sydney Opera House are so tightly modeled. But architects are not prepared for this work, sculptors are. It is a faint hope that architects and artists will work together from the beginning. (Giedion, 1941) [59]

Designers have also imitated the other periods, borrowing from them forms and techniques, with expressions that escape the transitory work and achieve something that was written by time. After a while their buildings turned into massive stone, despite incorporating details that in the architecture of another time we would appreciate as extremely attractive. These designers, according to Giedion, carry “the exact counter of the ‘Midas touch’—Everything they put their hands on turned to dust rather than to gold.” [59] To go back to another time, it is not enough to inspect it and find models and then use them as templates for your own structures. Cultural values are carried over time, but are transformed.

He observes that “The backward look transforms its object; every spectator at every period—at the very moment, indeed—inevitably transforms the past according to his own nature.” [59] He argues that there are no timeless standards in art, and that nineteenth-century painters and architects were mistaken in believing certain forms to be universally valid. Modern art, like modern science, accepts that “History cannot be touched without changing it. Modern

art, like modern science, recognizes the fact that observation and what is observed form one complex situation—to observe something is to act upon and alter it.” [59]

Cultural values can be repeated, but they can never be reproduced. The difference between the two, according to Gilles Deleuze, is that repetition refers to the recurrence or reoccurrence of something. [80] It is the process of transformation of patterns, actions or events. Deleuze argues that repetition is not simply a duplication of the same thing; instead, it involves a transformational and creative process. He suggests that repetition is not simply the mechanical repetition of identical elements, but also involves a play of differences. [80] If we were to speak in mathematical language, repetition would be represented by n^t while reproduction would be $n \times t$, where n is the individual and t is the number of transformations. As such, repetition preserves the significance of the initial product. Without it, the meaning of all its subsequent repetitions would be lost. However, this process gradually changes the first product. Whereas reproduction occurs when all the reproduced products carry the same meaning. If reproduction exists, then the object has lost its initial unity. To understand this, I will take the example of an echo, which is a repetition, in the sense that it originates from a sound and then its repetitions gradually change but always represent the source from which they were created. Repetition is continuous, creates variations, and introduces new elements at every stage of its transition. It is precisely through the process of repetition that new forms, ideas, and possibilities emerge. Repetition for itself refers to repetition as an active and self-generating process. It goes beyond mere reproduction and becomes a productive force in itself. Instead of repeating something identical, it also includes the repetition of difference. The fact that each repetition—in our case, each cultural period—introduces variations or small differences of the previous culture, creates a dynamic play between sameness and difference.

Consequently, I must first examine to find the basic values in design, which have been present since the beginning of the culture of the first man. I have already found two values, which are (1) the experience of man placed in certain situations and (2) his interaction with tools. Both of these influences would not have been possible without touching the realm of feelings. A problem with today's science education is that it is designed to produce extreme specialists. It is clear that there is an urge to collaborate among professionals and to overlap competencies. However, there is no institute to help us understand the connections that exist between different sciences or between science and the realm of feelings. Science is not an activity that runs independently of all other activities. Each period finds outlets for its emotions through different ways of expression. Simplicity gave the feeling of order in Modernism while experience gave the feel of intimacy in post-modernism. The influence of feeling has certainly also affected aspects of construction.

If one reads *Toward an Architecture* from time to time and the reader goes beyond the persuasiveness of its rhetoric, he will be confronted with a dilemma of the author. This

dilemma is his inability to define a clear approach for the concept of sensation. For him, mathematical concepts are absolute values because Le Corbusier associates them with the comforts of security and certainty. However, perhaps even the word “comfort” includes a flirtation with the realm of feelings. For Rowe, for example, it is clear that the selection of good forms in modernism—cubes, spheres, cylinders, cones—beyond the claim that, based on scientific calculations, they had good performance, in fact also had subjective sensory reasons. [31]

Mathematics and geometry are certainly not the only standards on which Le Corbusier argues his position against the Beaux Arts theory and the theories of the early 20th century. His book proposes programs of socialist realism, based on which, architecture—generated by function, structure or technique—should be able to take an objective stand by symbolizing the internal processes of society. [61] It soon became evident that symbolization as an objective public order of the values of society could not be achieved. In stark contrast to what it was supposed to achieve, this inability turned the modernist spirit to produce formal aesthetic aspects, which is an approach that Modernism condemned so much in the early years of its inception. The reason for this is that, instead of mathematical symbolisms offering certain formal conditions that represented the rules followed by society, they were actually absorbed by the senses as aesthetic aspects. As such, before giving messages of social order, they offered personal sensory experiences.

Another important thing, according to Rowe, is to embrace the loss of authority of designers due to the effect of the aura of the structure, which seems to have a soul of its own. [31] The aura that is carried by the structural object also undergoes its own transformations due to cultural changes. To explain this, let me refer to the case of the modern project again. It is clear that the design process of the Modernists was as rational and direct as their buildings. In addition, these buildings contain no rhetoric, no sentimental excess. However, there is a special quality of heroism and brutalism that characterizes the buildings of that period that those of today do not have. These structures do not compromise with their observers. They are neither capricious nor urbane, and they display an authenticity so complete that, in Rowe's words, "we are disposed to accept them as facts of nature, as geological manifestations rather than as architectural achievements." [31] Sullivan has a similar sentiment when he comments on the towers in Chicago of the early modern period: "In Chicago, the tall building would seem to have arisen spontaneously in response to favorable physical conditions...The Future looked bright. The flag was in the breeze...." [31] Even in the case of Chicago, we see the separation of the modern program from other styles before it was perfectly clear and this is reflected in its buildings.

There are also design values that clearly were not always part of the design and, as such, should be viewed with a skeptical eye. For example, one of the conditions that the modern project introduced was the rules of correct composition, and ideas for it were compiled and

put into various books. As for these books, Rowe tells us that their contradictory nature in relation to each other made their reading, instead of clarifying the design—which was the condition of the modern project—fill the architect’s mind with more doubts and contradictions. [31] Then, in Rowe’s words, “The composition books are judiciously disinterested, catholic, temperate, and pragmatic; the classic manifestoes of modern architecture are partisan, exclusive, inflammatory, and doctrinaire.” [31] In all the conclusions that Modernism indoctrinates, the latter expresses the conviction that architectural form can be designed only if it knows well the disciplines that impose structures and functions. However, according to Rowe, the rules of architectural composition contradict this claim. He noted that, in the view of these theorists, a building’s significance does not primarily stem from its functional or structural principles even if these contribute. Instead, it is understood above all as a composition governed by architectural principles and imbued with symbolic meaning, commonly termed character. [31] According to the composition books, the key to designing a good building is to have a good composition and a good personality. One of these books explains:

Proper character does not necessarily accompany the securing of good composition... A factory may display all the correct grades of classical architecture but may look like a public library. On the other hand a church may be recognized as a church on account of the antisocial elements—the spire and stained glass windows—but be entirely lacking of the principles of good design. Proper character and principles of composition are not synonymous; they appear together only by a conscious effort of the designer. They must both be present in a successful piece of architecture. (Rowe, 1982) [31]

Character is not pre-determined, but if it has meaning in design, according to Rowe, it can come from two reasons: from the individual applications of the artist and from the expression—symbolic or functional—of the purpose for which it was built. [31] Not every building in the history of architecture has needed character to be considered architecture. Some of them were valued solely for their performance values, without regard to symbolic or artistic value. That is to say, character, while valued, is not an absolute requirement. In the modern period, for example, theorists and critics opposed or ignored the value of character in structures. They considered it subjective, decorative, or too vague to be taken seriously as architectural value. Since both—history and theorists—have criticized the value of character in buildings, this concept becomes problematic. It cannot be said that the character of structures is a primary cultural value, nor a basic value for structural design. This investigation does not mean that the concept is irrelevant. However, it means that it needs further exploration and can perhaps be considered depending on the design situation.

There are also design values that have disappeared once and for all (for good). For example, there is something about the juxtaposition of the words “ethics” and “formalism” that drives me mad (subjectively speaking, but it doesn’t make my argument wrong). It happens when

architects babble about building ethics as if “sincerity” in structures and details somehow fulfills some moral purpose. Or when some theorist argues that a properly manufactured brick shows that the manufacturer is careful and by his care is demonstrating a moral stance. Or the sentence “Whitewash is extremely moral.” [81] by Le Corbusier. The latter is not alone in this absurdity. The connection of formalism with ethics has settled very early in structural design and architecture. This way of thinking is responsible for the delusions of an absurd world where morality is linked to objects. The statements below belong to some famous architects:

"In a long life I have become increasingly aware of the fact that the creation and love of beauty not only enrich man with a great measure of happiness but also bring forth ethical powers." [64], Walter Gropius... "The mass production house, healthy (and morally so) and beautiful in the same way that the working tools and instruments which accompany our existence are beautiful." [61], Le Corbusier... "To us clarity means the definite expression of the purpose of a building and the sincere expression of its structure. One can regard this sincerity as a sort of moral duty." [8], Marcel Breuer... "I was left with a deep conviction of the moral rightness of the new architecture." [82], James Stirling.

Architects can only believe that beauty, materiality, or structural sincerity are considered to have some ethical purpose only if they isolate themselves in a parallel universe. [8] By this, Till means that structural designers, and architects, in general, withdraw themselves into a scale independent of human and social aspects, where morality is associated with the rectitude of architecture as a profession of fine, superhuman, and predefined aesthetic detail. Only under such superhuman pre-conditions—Holy Scriptures established by the Gods of Architecture—can one believe that there is an ethical stand in objects, which is established as the norm of society. This kind of approach has its source in the definition of ethics as “if there is a definitively right and proper way of doing things”. To consider ethics as defined above is to act as if contingency does not exist. Emmanuel Levinas suggests another notion of ethics as “being-for the Other”. [83] In this case, “ethics” as a notion, means being responsible towards others. This is the concept that Till suggests should guide architectural design and has always been one of the basic values of structural design: an activity in the service of man. [8] The service rendered is to the builder, the user, the observer, whose life will be affected by these structures. From this definition of ethics, several implications emerge with regard to structural design. First, since structural design is primarily concerned with spatial experience, it means that the focus of ethical attention should be on dynamic social space, not on the science of structural statics, nor on aesthetic aspects. Second, people’s needs are different from those of clients, which means that ethical stances must be sharply separated from the norms of professional services, which are primarily concerned with client demands. Third, the spatial and social conditions of the spirit of our time must be weighed against a new sense of ethics—one concerned with service to others. Finally, these “Others” are diverse and unpredictable, and the new ethical approach, as well as the values

of the structural design of our time, must allow for change rather than stifle it under a pile of claims for universally moral things.

Regarding the last implication, Canguilhem explains that tolerance involves acknowledging a plurality of values and resisting the elevation of any single one as universal, whereas intolerance represents a kind of normative imperialism. [36] Yet he observes that “a plurality of norms is comprehensible only as a hierarchy”, since norms cannot exist equally without stripping them of the institutional, cultural, or legal decisions that make them effective. For him, “a norm cannot be normative without being militant, that is, intolerant”, which means intolerance carries hatred, while tolerance often carries contempt. [36]

Values tolerate what they deem to be valueless. Eighteenth-century relativism and tolerance were inseparable from the fundamentally normative idea of progress. However, progress was not achieved in terms of the connection between values. It was identified with a final social value that stood out from a series of values, transcended all others and served as a standard—a means of judgment—for them. This is why tolerance was the value in the name of which someone was persecuted as intolerant and relativity was the value in the name of which someone was judged as absolute. It is not enough to be tolerant of cultural conditions.

The mere fact that the spirit of the time accepts conflicts and accommodates them does not mean that we have reached a stage of enlightenment as a society. On the contrary, the main claim of society that has taken root since the conception of the modern project is that the current values of society will be transformed and evolved into an ideal society. Consequently, there is very little desire to return to previous values. “The only true remedy lies in the invention of new norms.” [36], says Canguilhem. Social changes carry with them norms, which are transformed, but never discarded. Which means that we must judge norms while always keeping an eye on the possibility of devaluation in a normative sense, but never erase one page and start another.

However, Canguilhem also warns us: “Generosity of spirit is to be imitated, but, belied in the efficacy of immediate solutions, must be rejected.” [36] Which means that the desire to do good, accompanied by the efficiency or performance of form towards an objective, is transformed and loses its values. This does not mean that we should not set objectives for our project. Of course, this does not mean we do not carry any structural design values during our work. Simply, it means that one (good intent) and the other (structural performance) are two different things.

This is where creativity comes into play. Canguilhem states: “There is one sure criterion for identifying creativity: a willingness to put norms to the test, to ascertain their value fairly and without trying to make them seem artificially normal.” [36] The normal is that which adapts to the environment in which it lives and becomes normative, but not everything normal actually becomes normative. To be such, it must acquire a general status, that is, it

must be tested in all the varieties of the environment in which it is found. So, practically, the determination of norms comes from a history of its positive data against the environment and in this sense, as Canguilhem also says, “the history of the world is the judgment of the world.” [36] In this sense, the designer’s task is to question the values of the time and to design by judging them. Then, starting from the interaction of people with the work, it is up to Others and, afterwards, history, to answer whether a value should be transformed or not. Great works have been those that have brought about changes in the norms of society. As long as they carry the message of judgment about the value of society—be it a message of validation or denial—they are predisposed to be mentioned by history. Technological normalization means defining standards for materials, shape and size so that objects can be manufactured without problems. However, society is not only technical—it is also economic and legal. The demands that come from technology (for example, simplicity or efficiency) can clash with the demands that come from economics (for example, cost, and market readiness). Engineers, for example, may want to simplify their project but businesses may resist because of the value of the project’s product in the market. As a result, technological norms must negotiate with economical norms or other fields. Normalization must be flexible, not rigid. In fact, the word “normalization” was chosen by the French in the 1930s to avoid choosing the word “standardization” precisely because normalization left room for flexibility. Even when design values are validated by history, there is still room for contingency to override those values in certain situations. “Norms must allow for divergence”, [36] says Canguilhem. Indeed, you cannot weigh all human values or social behaviors in the same way that you can weigh a factory-made nail. Normalization is not a fixed or rigid process; it must remain open and respond to human variability.

When norms of different fields clash and overlap, this is called “Planning”. “To plan” means to try to manage the whole system to work together, which comes from the demands of the modern project to necessarily establish control. Of course, planners are deemed to fail in the sense that they cannot provide the best solution because they do not have the opportunity to know what is best for all groups of interest. Yet, planning is useful: It is a way for society to self-organize regarding its needs. Without this, society would be driven by the needs of the market, just as structural design—rejecting the values of design—is driven today by the needs of the market. Planning cannot claim to solve everything, but it is an attempt to organize society consciously and collectively.

Society ≠ Organism: In an organism, its parts—organs, for example—do not need to be trained for the rules that the organism sets. In a society, rules are external to people. They have to be learned, remembered, and enforced. The organism self-regulates—through homeostasis, for example—while society needs to build structures to regulate itself—through laws, codes, regulations, institutions, etc. So, while biological regulators are automatic and internal, social regulators are external and constructed. Even in societies that are considered emancipated; it comes a moment they need to improvise because sometimes

things do not go according to plan. Social needs and biological needs also differ in the same way. The needs of the organism are immediate, such as hunger and rest. The needs of society are ambiguous. When someone asks “Is this really what society needs?”, he lets us understand that that norm is not shared by all. Finally, regarding the norms of society:

We then discover that no society is fundamentally good, but that none is absolutely bad; they all offer their members certain advantages, with the proviso that there is invariably a residue of evil, the amount of which seems to remain more or less constant and perhaps corresponds to a specific inertia in social life resistant to all attempts at organization. (Levi-Strauss, 1981) [84]

The enlightenment of society, the modern dream, falls at this moment. No social structure can completely eliminate dysfunction. It cannot be an organism because it lacks true harmony and immanence. It cannot be a machine either because a machine is too rigid and idealized. The values of society represent it; as a complex, imperfect, hybrid conglomerate that must constantly negotiate and question its own norms.

Despite this, attempts have been made in architectural design to rationalize and formalize design and to make it resemble an organism, claiming at the same time that this is what society demands of them. Rowe argues that when architecture rejects mere fashion or arbitrary novelty yet still calls itself “modern”, “new”, or “contemporary”, these terms must carry meaning beyond the purely chronological. Just as “organic” architecture suggests a link to biology, “modern” architecture invokes a standard of contemporaneity. Following Gropius, Rowe notes that the new architect is “the inevitable logical product of the intellectual, social and technical condition of our age.” [31] This implies that for a building to be truly modern, it must not only respond to function, structure, and materials but also embody the more elusive dimension of the spirit of its time. [31]

It was an idea that raised modern architecture above rationalization and norms it was seeking to decide. By claiming that their product was inevitable and came about because of the spirit of the time, they elevated their products above the products of previous eras. “...the will of the epoch transplanted into space.” [31], expressed Mies van der Rohe while at the same time saying “it [architecture] should exclusively be: building.” [31]

Rowe speaks of this dualism by pointing out a tension in Mies van der Rohe’s work, noting that he had long been grappling with a fundamental dichotomy. [31] If architecture is understood as “simply rational building” while also serving as “the embodiment of the spirit of the age”, then two conclusions follow: either the spirit of the age is purely materialist, defined entirely by technology, or it is so refined in its selectivity that it accepts a purely technological expression. [31]

If both of these claims are not true, then the only possibility is that the spirit of the time is mere bulding and nothing more. "The spirit of the age can be indiscreet. Rationalism never." [31], says Rowe. What really happened is that at a certain moment both sides "shared many of the same interest so they made an agreement." [31], he says. The spirit of the time was enthusiastic about speed, mass production, airplanes, sun cream, excavators, simple living, factories, hygiene, etc. All these things were created in the interest of the spirit of the time, without questioning their other values such as aesthetic aspects. But when the first criticisms of their aesthetic form began, the division between technique as the only value and the values of society became visible again.

Total determinism cannot be a design value neither in the design method, nor in the form of the structure. Peter Rice challenges the belief that technological choices always follow a predetermined logic or that there is a single correct solution to a technical problem. [85] He argues that every technical decision is only a temporary resolution, the outcome of a complex process involving the analysis of information and judgments made on available evidence. Such decisions are shaped by a particular time and place, and by the people, their backgrounds, and their talents. Too often, he notes, the human role is obscured in a "black box" effect. Yet by exploring new materials, or reimagining traditional ones, the presence of human creativity becomes visible again. [30]

As a structural designer, he understood that a technological device is a cultural choice and is not simply a matter of reductive logic. This also applies to computational optimization processes, which are automatic, mindless processes. Emergencies or even ethical reasons to increase the performance of the building—such as sustainability—do not justify the use of these methods in design without first developing a methodology that also includes the human touch.

As for the human touch, Martin Heidegger states that our understanding of space is found in the spatiality that we have [86], and I have already shown in this thesis that this notion gives space another meaning: that of phenomenological space. A phenomenological space cannot be abstracted only in geometric forms but must be understood as our interaction with the world. Even man makes space. It is a notion that Till calls "space-ish humans". [8] Design in this context requires the designer to imagine his own spatiality with the structure he is designing, taking into account that some aspects of human spatiality are common to all people. Such are the requirements for light, for being above and not below, for directionality, for having privacy, for not feeling noise or vibrations, and so on. Structural design thus becomes not a matter of modifying the abstract model of the structure to adapt it to the environment, but a spatiality that shares cultural and social dispositions.

That said, starting from the fact that human experience carries shared social values—without denying individual values—and since experience is necessary for design, a good way to

design in this era is by having participation. However, as Kojin Karatani also said, “...because architecture is an event, it is always contingent.” [87] Which means that participative architecture is a form of communication that tends to happen without having shared rules, nor shared knowledge. Through it, a person communicates with others who do not follow the same rules as the first. In other words, someone who has a set of rules and values (the designer) seeks to design a structure for others who do not want to be involved at all, nor to understand his values.

Renzo Piano also supports the argument that there should be proper participation in design. He emphasizes that if an architect cannot listen and understand people, he risks creating buildings only for personal fame rather than fulfilling his true responsibility. [88] For him, an architect must be a craftsman, regardless of whether the tools are computers, models, or mathematics. What matters is the unity of mind and hand, a circular process that moves from idea to experiment, from construction back to idea. Too often, he warns, these steps are treated as separate when they should remain interconnected. He adds that genuine teamwork depends on the ability to listen and engage in dialogue. [88]

However, contrary to Piano's words, we must understand that it is not enough to try to understand others or to dialogue with them. You have to invite them into the design. To ask for a real participation.

One thing is certain; except for some special cases where the design is so conditioned and situational that it can be intended that the designer has complete control, in general he does not have this luxury. One of the reasons for this is specialization and the impossibility for a designer to master all the fields from which his structure is influenced. A prediction of what these aspects may bring to the field of architecture comes from Frampton, who argues that architects must increasingly guide the various branches of the building industry so that each develops its components within a shared tectonic framework. The architect's role then becomes one of refining and coordinating these elements, since such integration remains the only responsible way to realize large-scale constructions. [30]

This thing has been done, but it has been done badly. The point is that architecture and structural design, in the words of Giancarlo De Carlo, lost their credibility when “[designers, academics and business] position[ed] themselves on the side of the client rather than on the side of the users.” [89] Historical experience has taught us that the elite, even when they claim to maintain a neutral stance, find themselves used by interest groups that gladly accept their neutrality, because only in this way they can exercise complete control. This neutrality is also the reason why structural designers choose to deal with the problems of “How” instead of dealing with the problems of “Why”.

Nevertheless, perhaps Frampton's words hold a glimmer of hope. Perhaps Tectonics represents the values of structural design in the spirit of the zeitgeist, since it links architectural values with structural values.

He explains that much of architecture, including the celebrated manipulation of space, is intertwined with the lifeworld and belongs as much to society as to the individual. Yet "the culture of the Tectonic still persists as a testament to the spirit: the poetics of construction." [71]

What Frampton wants from Tectonics is to guide designers to express the pure logic of construction and the way in which the work is built. He does not want the work to necessarily contain images that visually show the method of construction. He wants to connect the construction phase of the work with its life after completion, thus breaking once and for all the misconception of the work as an object with an expiration date and introducing the full notion of time. In this way, the right brain and the left brain will be connected again.

The problem with Tectonics is that it is too intellectual. If we ask for proper participation and proper ethics, the complicated language of Tectonics is easily misunderstood by Others. The latter do not share the same obsessions that designers, who apply the principles of Tectonics, may have, for example for articulated joints or "both-and" details or "both-and" structures. This language belongs to an elite and is spoken by very few and the problem is that it is very easily misunderstood (or even ignored altogether). Articulations are at first glance misunderstood as aesthetic values and the theory "that the structure is representing architectural values" makes observers connect aesthetics with values in general and go even further; to think that there is ethics in aesthetics. This gives nothing but phony structures. As such, it sends the message that "as long as you 'Others' come and join us in this parallel universe, you can have access to these aesthetic standards." As a result, ethical issues are no longer made through the active participation of Others, but are situated in a highly controlled environment that positions the designer as the arbiter, in the sense that, if Others do not have sufficient knowledge of Tectonics, they are not allowed to express themselves because they lack taste. This approach is generally shared by architects and goes beyond the values of Tectonics. Whatever principles architects follow, they usually operate within their own professional domain, convinced that their choices are justified, while outside forces frequently interpret these same choices as marginal, limited, or even imposed. As a result, the architect's figure is often portrayed as disconnected from the outside world.

Structuralism is indeed a strong concept that provides analytical tools. However, this does not imply that the principles derived from such analysis should automatically be transformed into values of making architecture. Nor does it guarantee that the people who use a "finished building" will be able to recognize or interpret the underlying systems that made it happen. When users do manage to perceive something beyond the immediate appearance of a

structure, it is usually because they are already acquainted with the formal discourse surrounding the autonomy of structural design.

Whereas regarding Tectonics, its worst flaw is its reliance on ethics of aesthetics. Till argues that the deadlock in architectural thinking may come from the tendency to equate visual order with social order, a move that leads to reification. [8] By turning ethical ideas into aesthetic objects, ethics becomes abstracted into something other than itself. For Till, ethics is fundamentally about responsibility for others and rooted in social relations. Thus, when architects engage with ethics, they must engage with how social relations unfold in space. Tectonics undermines this by freezing social dynamics into beautiful, refined objects, which distance both viewer and viewed from everyday life. In doing so, architecture severs its connection to ethics as it is lived in social and spatial relations. [8]

To put it in simple terms: a brick has no morals. Whereas the careful placement of two bricks together, contrary to Mies van der Rohe's claim, in fact, in the words of Beatriz Colomina, "[is] just about the dumbest definition of architecture that I have heard." [90] People do not really rise to another level when they appreciate the beauty of Tectonics, Tectonism or any other style. Fluid shapes do not represent the ethics of movement. They are at best simply geometric figures. At worst, they are architectural conveniences of abstraction of the world and its depreciation into a place where taste is the property of architects. When someone says that a structure is unethical, this does not mean that we should all focus on its appearance or materiality. By this, I do not mean to lobby for ugly or dull buildings. Simply put, Le Corbusier's claim that "people who wash their shirts, paint their houses, clean the glass in their windows have a different ethic from those who cultivate dust and filth." [91] is so wrong in so many ways. According to him, bad aesthetics equals bad ethics, and good aesthetics equals good ethics. Therefore, according to him, if we clean architecture, we will have a clean society. However, society depends on so many forces that the problem of aesthetics is a minority and the relationship is not linear at all. This does not mean that we do not consider aesthetics at all. This does not mean that tectonic articulations do not have their values in certain cases. On the contrary, we saw in previous subchapters that Tectonics and Tectonism were good solutions for many cases. However, in the small list of values that architecture or construction carries beyond their shell and beyond time, there is no place for aesthetics—nor Tectonics or Tectonism. If these values are to matter, then they will come from situated approaches, case by case. This relieves the pressure on construction: a built object does not necessarily have to be beautiful. This approach also goes with the post-modern spirit where architectural objects are seen as "both-end", "yet" and "partial". The main value of construction—the true ethic—remains construction in the service of others. If the concern for the articulation of details or the aesthetics of the overall form of the structure derive from the designer's concern to perform a service to others—this includes everyone's life affected by the work, not just the client—then yes, the values of aesthetics and Tectonics or Tectonism, as a style, are welcomed.

There was once a time when social values, architectural values, and structural design values were intertwined. Everything changed when the modern project attacked. With its iron fist, the modern project divided the professions and gave each of them a basket of corresponding values. Of the many different fields that were divided, worth mentioning are: Society separately, natural sciences separately, engineering separately, art separately, computer science profession—most recently—separately, etc. Philosophers talk about the values of society, natural sciences about phenomena in the world, engineers deal with technical aspects, artists deal with the emotional aspect and experience, while computer science with the potential of the computer. These spheres of action do not often meet, but even when they do, professionals rush to defend the values of their basket, seeking more authority for themselves. In this division, the activity of construction, and especially that which has to do with design, is particularly confusing. The structure is evaluated against strict objective criteria that come from the direction that engineering has taken (bearing capacity, stability, allowed deformations, seismic performance, etc.). Its form is at best evaluated according to artistic criteria (aesthetics, expression), at worst it is not considered at all and is required to be settled inside the building without much fuss. Computer science has helped a lot in modeling structures, but even they do not want to participate in the inherent aspects of studying the structure. Therefore, both sides—engineering and computer science—have made a silent alliance: Programmers have created software that are good enough to analyze models of typical structures, as long as this system is closed (in programmers' language, it is called a black box). Which means that the structural engineer does not have access to computer language. He only sees what he wants to see to meet the criteria of his expertise. The programmer at the same time finds it easier to create situational closed-end software. Therefore, the benefits go both ways. As for the social aspects, experts in this field also do not want to be involved at all in the construction of structures. Therefore, their interventions come only before and after the construction process. It is as Barbara Herrnstein puts it: “Unable to accommodate the idea of a world conceived otherwise, objectivist thought concludes that, in the absence of its own conceptualizations, there could not be a world or any thought at all.” [92] The only field of construction that seeks to mix things up a bit is architecture, but even that discipline seeks to distance itself from the great tangle of technicalities that accompanies the design of structures. Very few architects dare to design structures by applying architectural principles. However, the problems that structures entail do not care what profession someone has. They seek solutions. The best solutions never come from a specific field because solutions themselves are options from reality. Reality is never separate, as the modern project demands. Structures themselves are quasi-objects. As Till points out, “Quasi-objects, with all their hybridity, are part of the networks that the modern project ruled out of court.” [8] However, according to Latour, these quasi-objects have never gone away. [93] Modernity felt this too, but their thesis was that a day would

come and their actions would be rewarded when quasi-objects were eliminated once and for all. For this reason modernity as a movement was a tentative process. “We have never been modern in the sense of the Constitution (of the modern project). No one has ever been modern. Modernity has never begun... modernity is much more than an illusion and much less than an essence.” [93], says Latour. His observation reduces the pressure for perfection that each area of specialization demands in modern design. It allows activities and processes such as structural design in particular and construction in general to be treated as they really are: as quasi-objects. Structural design can return to its pre-modern place as an activity for people that encompasses all the aspects that man requires of structures and processes that deal with them. In this light, Till notes that networks emerge which link the local with the global and the human with the nonhuman, and these interconnections provide a renewed framework for interpreting the overlapping domains of science, culture, and architecture. [8]

Accepting the value of structural design as a social activity does not mean accepting the relativistic “anything goes” approach. This has in fact been one of the criticisms of postmodernism, which is accused of having contributed to the collapse of the world into a common relativist mindset, deprived of any significant values. However, Latour argues that this is precisely the approach that the modern project demands. There are two sides to the modern project; either you accept the rules without questioning them, or you accept that there are no rules at all and no values at all. [93] “...the horror of mixing reflects the obsession with separating.” [39], states Bauman. However, as long as the rules of the fields of modernism are insufficient for solving problems, contingency is released from their clutches and the rules are put into question until a situational solution is provided.

Contemporary structural design’s obsession with formal taxonomies has arisen because of the power of the computer to generate forms and influence designers. Thanks to computers, a series of new structural forms have become possible that no longer fit into the classical system of classification of structural elements, and structural designers are now engaged in the study of these forms. “There is so much visual noise in the internal systems of [design] that one cannot hear the external world.” [8], says Till.

Even Sanford Kwinter expressed the same worries when he writes that despite their technical virtuosity, the recent developments “have never managed to hide their fundamental aimlessness, the inevitable result of cultures whose intellectual activity has become severed from its foundations in social, historical and economic life.” [94]

The attention should come back to humans and in particular to improve human conditions. As for the tendency of contemporary designers to express the activity of construction as its human conditions rather than as an attempt to improve the human conditions, Till replies, “I suspect the answer is disturbingly simple: it looks good.” [8] By presenting society as it is at a given moment, without entering into the problem of improvement, the designer is

excluding time from the equation. By excluding time, he excludes the project out of this world and with it, all the social demands that await solution. In this respect, both classical and contemporary structural design are complicit. Till puts it this way: “The traditionalists and the progressives are therefore but two sides of the same conservative—and amoral—coin; the only real difference between the two camps is that the traditionalists are more honest in admitting to their conservative tendencies.” [8] He adds that both positions ultimately share a view of time in which instant pasts or instant futures are reduced to static formalist gestures, paradoxically erasing the very temporality they attempt to evoke. [8]

Therefore, structural design, in Latour’s terms, must be merged as an activity with other fields, especially the social aspect of design. In today’s world, what is needed is a “hybrid” structural design, in Latour’s words, and a “lo-fi” one, in Till’s words. Both ideas suggest a structural design that does not only deal with problems of load-bearing capacity, but also embraces social and ethical values. That said, attention is diverted from the structure as an object and goes to the negotiations of much more complex interconnections that the structural designer must bring together at a table. Lacking eternal knowledge, the structural designer is deemed to fail. Therefore, the design process needs the participation of as many affected parties as possible and cannot be left to the structural designer alone. This participation—as we have already seen in chapter 2—does not improve the design by default. Therefore, the structural designer must be ready to negotiate, to protect the basic values of design—such as service to people, structural performance, human experience with structures etc.—when necessary. Structural design is intrinsically linked to the cultural values of society. However, structural design does not only carry the values of contemporary societies. In fact, it holds all the values of all societies in all times. These values are potentially possible within the new basket of the structural designer. Some of them, such as structural sincerity, the ethics of aesthetics, and even mere functionalism, have been rejected by contemporary society. Others—such as sincerity, simplicity, or tectonics—are valid or not depending on the situation, and it is up to the structural designer to reflect on them.

Before I try to channel these principles into a methodology for structural design, I must state the obvious, which has been mentioned time and time again throughout this text because it seems inevitable: Structural design today is closely linked to the use of computers. Here there is a contradiction, because our *zeitgeist* asks us to accept contingency, but at the same time, it asks us to use a completely deterministic language, which is the language of the computer. We must be careful here because these two aspects of the *zeitgeist* conflict with each other; they go in two different directions. For this reason, I will study in the next chapter what are the values and limits of computer language in order to set a method that embraces determinism when it carries values, and leaves room for human touch when computation is limited. Without this, structural design will be consumed only by the values—if there is any—of the computer program.



Figure 58 - Barcelona Tower, project proposal in Tirana (Image courtesy of Bofill Arquitectura, source: <https://www.bofill.com/projects/barcelona-tower/>. Used here for academic purposes) [95]

The Barcelona Tower project (fig.58) in Tirana quite evidently screams “Grasshopper”. Such computational programs as Grasshopper and Dynamo, with or without intention, have brought an urge among their users to build such images similar to this project. Even architecture students are inclined to click on “rotate along the axis” and be amazed by the generated forms so much that they embrace them as their own projects without resistance at all. At universities, when students learn these software, they are eager to produce similar shapes (fig. 59).



Figure 59 - Projects of third-year architecture students, CAD3, POLIS University, 2025. Guidance: Fulvio Papadhopulli, Flavio Çyçi, Markelian Lleshi, Joni Zguro. Photograph by the author, 2025

Mostapha Sadeghipour Roudsari, the co-founder of the Ladybug tool, which is a Grasshopper plugin, protests against this observation with an ironical tone:

If I were in charge of the Rhino and Grasshopper licensing policy, I would have put a one-month license ban for building twisty towers in Grasshopper. Three months if you LinkedIn that nonsense. Six months, if you LinkedIn that nonsense colored with some radiation studies using Ladybug Tools, claiming you are a sustainability expert or care about sustainability. (Roudsari, 2025) [96]

Schumacher, on the other hand, does claim that new forms in contemporary structural design have come about because of the need for higher performance of structures [11], but this is not necessarily true. There are cases like the ones above when the simulation itself influences the designer and requires him to produce certain forms.

The relationship between the tools used to study space and the way we perceive space, or how our mind interacts with the creative processes during design, is a dynamic and, among other things, dialectical process. There is a conversation between the designer and the computer at all levels of design and this conversation is not just “the man speaks, the computer answers”, nor vice versa, but it is a “give and take” conversation. The influence of these tools has played a fundamental role in avant-garde design also due to the urge for “technology flexing”, which is related to urban development and novelty and, consequently, to the avant-garde. Even throughout history, theoretical and technological research have influenced the creative part of the mind of structural designers and architects in general. The advancement of “theory of perspective” triggered a spatial revolution that characterized the Renaissance period, both in the physical and intellectual articulations—with perspective drawings—of space. In the same way, the parallel rules established by the authority that various professions took on, created the modernist way of understanding space. A similar influence is being seen today in the use of code base design and the so-called AI.

That is why it is important that the values of the computer program—what it really wants from design—along with the potential and limits of the computer in design, need to be explored in the next chapter.

4. COMPUTATION TAKES COMMAND

Chapter 4

4.1 Computational Structural Design

Structural design today is International Structural Design. Every project of structural designers is immediately exposed and placed in comparison with all other projects. This does not mean homogenization or monotony. It merely implies a set of common principles, to establish the conditions of common progress, instead of design styles following contradictory principles with each other, which may lead nowhere as a common social spirit. It is about the idea of a common style, which first began as a common avant-garde research program and gradually became a common system of principles, ambitions and values that regulate the best global practice. Structural design today has clearly not reached its potential. In the words of Schumacher, “the structural design community is still flexing its muscles rather than going to work with a clear social purpose.” [11] In many new design studios and universities, parametric design programs are being played with and explored. Parametricism—as a methodology—faces a difficult challenge: the time has come for structural design to include and organize the complexities of social life. Parametricism is already helping with calculations and automatic processes. For example, a designer who knows how to code is able to build programs that repeat mechanical tasks themselves and save designers a lot of time. Not only that, but through computational programs, structural designers can navigate and explore more quickly and more deeply on the structural model, achieving objectives that were previously impossible to achieve.

Since the 1970s, structural designers have relied on the computational power and speed of electronic computers. Before computers, structural designers relied on formulas to analyze specific structural shapes. Now, with digitalization, computers allow us to analyze all shapes of structures, to take into account nonlinear behavior or second-order effects, and to automate the detailing of structural design. Computers have also revolutionized other parts of structural design work: in the words of Debney, today in England, “whereas before there were five drafters for every structural designer, now there are five structural designers for every CAD technician”. [6] Structural design teams have become more productive and have used the power of computers to create more complex structures and structures that perform better against design objectives. Design is changing, construction is changing, and the environment is changing. New materials and new technologies are emerging. In this complex world, we need to understand how to use computers and what to do with these new methods and things. Above all, we need to understand what the role of the structural designer is in this new world. When the so-called AI can generate structural designs, FEA programs can analyze them, optimization methods can improve them, and other programs can automatically generate drawings, as well as validate all the steps of the process, what are we need for? The answer is that machines can do some things well, such as mathematical calculations or checking hundreds of options much faster than we can, but they are also very bad at other things. Computers do what they are told, they do not understand (in the human

sense of the word). They can explore much faster, but they cannot invent new things. They can check and solve problems that have occurred in the past, but they cannot do this for problems that have not occurred, and they can never meet with the client or discuss project problems and negotiate with contractors.

“Architects do not make buildings, they make drawings of buildings.” Robin Evans [79]

Similarly, structural designers do not make structures on a computer. The computer only makes models of structures. These models can take many forms. They should be conceptual diagrams that show how the structure and building will behave. Since construction is a multi-process activity that takes place in an unregulated environment—not in a factory, for example—it is quite inefficient. Some of these activities—model analysis, for example—can be made even more efficient, and can even be automated. However, there are other processes for which efficiency as a concept does not work, nor does the use of a computer. The computer has mathematics at its core. It has come to a point now that computers have become so good at calculations that it is pointless to compare them to humans in this aspect. They are faster, more accurate, and they never get tired. Nevertheless, they are so stupid that they cannot do anything without being told in advance. Even in today's times, when it is claimed that computers can learn new things, we are still the ones who tell them how to do it. They cannot think, much less imagine. However, they can explore possibilities much faster than we can.

When Deep Blue defeated the world chess champion at the time, Garry Kasparov, it did so by testing millions of possible moves and choosing the one that allowed it to continue the game without losing an advantage in position or pieces. On the other hand, fast forward 30 years later, the former world champion Magnus Carlsen, after winning an international tournament, states that time played an important factor in the pressure of his opponent and his strategy was to force his opponent to make mistakes. “Sometimes”, he says, “it’s better to do nothing, so that your opponent makes the wrong move.” [97] His opponent, the 2025th world champion, Gukesh Dommaraju, after the loss, said that Carlsen’s game was “a total mess.” [97] Supported by other chess analysts and experts, it seems that this game—at least at a championship level—is moving from memorization strategy and applied theory to a game of psychology and patience. Computers are still, 30 years later, undefeated at chess, but the confrontation between two humans seems to not respect the rules set by computers. The reason is simple; we are different. However, the fact that computers have become better than humans in certain aspects, such as the game of chess, makes us question our own performance. That we are different, it can be proven, and we will see in the next subchapters, but do we actually perform better than computers? Moreover, can we escape from structural formalism like structural typologies, by using automated workflows like FEA and optimization methods and, by default, address structural design with topologies—which are the forms dictated by the use of “finite elements”? This is a complicated question and the

answer will probably be: in some cases “yes”, in some cases “no”. In this chapter we will discover the values of computational structural design and we will find out in which cases humans are better and in which cases computers are better, as far as designing a project is concerned.

One of the big problems we face as structural designers is that we can only solve simple problems by hand, since the calculations increase exponentially as the complexity of the structures increases. This means that we are dependent on the FEA method to analyze structures, and this method can only be practically made possible by using computers. Since we need to analyze structures and provide good solutions, we also need to first create a model that represents reality, giving the characteristics of the materials, the shape of the structure, etc., as accurate as possible. We also need to question the work of the software from time to time. We do these things through validation and verification. In the validation process, we question the answers obtained by the computer. This could mean “if the software does what it is supposed to do”, or it could mean “if the software is suitable for the job you want it to do”. Whereas, the verification process deals with how accurately you have represented reality in the computer. Both of these processes are difficult because we expect both of these answers from the computer and we are in a situation where we are trying to set a criminal on trial while he is the judge. Therefore, we need to have a general idea of the correct answers before we use the program to find them. For example, in the case of structural design, you need to know what the deformed shape of the structure will be, what the moment of inertia might be, etc. Of course, the computer serves us for much more than just analyzing models. Sometimes it serves to experiment with new forms. Even with them, care must be taken to validate and verify, having an initial idea of what the answer will be. When your expectations do not match, this can be due to several different reasons. First, you may have made the model wrong, and you should check it. Second, it may happen that the answers are actually correct, but your expectations are wrong, and you should question your knowledge. Third, it may mean that the software also has errors or is not suitable for the job. Human errors that often occur with structural modeling can come from confusing the direction of loads, adding one zero more or one zero less after the numbers, errors with units, etc. Such errors have led to collapses of bridges or structural works, so they should be treated cautiously.

As for the wrong expectations, I was once analyzing a structure and the moment diagrams came out of the program in a very strange way. A small beam had its moment force entirely in tension only in the upper zone. What I expected at the time was the classic moment diagram of a continuous beam, with tensile forces at the top at supports, and at the bottom in the middle of the span. I later discovered that this phenomenon actually occurred in cases where the stiffness of the adjacent beams was so great that they pushed the end forces up too much, causing the tensile force at the bottom to also rise up and cross the neutral axis. Having wrong expectations is an interesting and a common problem, as it is normal not to know everything, especially at the beginning of your career. Therefore, if you are in doubt, it is

always a good idea to consult with colleagues who have more experience. As for the third problem, that of software errors, the main thing is to have enough knowledge of the program to know the field it covers. It may happen that you are using a software that does not do the job you are looking for. One such case is Karamba, a plugin in Grasshopper, which analyzes structures. The problem with it is that this tool is not designed to perform dynamic analysis. If you do structural analysis with Karamba, you cannot expect it to give you good results for structures in areas with high seismicity. For that, you should use another software that is made for that job. Another problem related to the performance of the software is that it can have bugs. For those who do not code, the software seems perfect, but those who know how to program also know how easy it is to make mistakes in coding. With programs that are used frequently, it is uncommon to encounter a bug, because from their frequent use, bugs, if any, have been identified, reported, and fixed. Personally, I have encountered three bugs while working with Grasshopper, which have not been fixed to this day, and Grasshopper is a program used by millions of designers, so you should not take it for granted that programs that are used frequently are bug-free.

The process of calculations in structural design has been transformed by various methods as technology has advanced. By the end of the 18th century, slide rules began to be used, which simplified the work because designers no longer had to look up logarithms in tables to solve standard structures. Designers adapted to this technique and automated the drudgery of multiplying large numbers, thus creating space to explore different structural possibilities without being overwhelmed by calculations. Later, slide rules were replaced by hand calculators. Many structural engineers initially opposed the use of these mini-computers because they did not allow people to reflect on rounding errors. However, hand calculators became inseparable from the design process, so much so that university professors often reminded us “not to become completely dependent on hand calculators because when we needed to do a calculation, we would not always have one in our pockets”. With the advent of smartphones, their claim also falls, although, however, mental calculations still have their usefulness in certain situations. Moreover, hand calculations are also useful during structural design, to check the results. Computers are essentially not much different from the devices I mentioned. All of these devices, including computers, rely on the ability to perform mathematical operations. Nevertheless, unlike the above devices, smartphones and computers can use numbers to represent other meanings. Numbers in this case can appear to us as loads, structural elements, structures or even people (how close to reality these representations are though, it is another matter). What most structural designers appreciate today in using computers is that it helps them solve tedious repetitive mechanical problems by giving them the opportunity to deal with other more important issues during the design. Among other things, structural designers view coding positively precisely because it helps them take mechanical problem solving to the next level, automating everyday processes.

Al Sweigart, with the text below, best reflects the help that the computer gives for mechanical problems:

"A computer is like a Swiss Army knife that you can configure for countless tasks. Many people spend hours clicking and typing to perform repetitive tasks, unaware that the machine they're using could do their job in seconds." [98] He recounts how a colleague, still a beginner in programming, developed a small script within a few hours that compared competitor prices with a store's database—a task that normally took several people two full days to complete. While most of his time was spent consulting documentation, the program itself executed in only seconds. [98] Such experiences are common nowadays.

The good thing about the time we live in is that coding has become very simple. From typing 1s and 0s, or memorizing programming languages that took years to master and much longer to perfect, coding has now become almost as easy as writing to the computer via chat using human language (English, for example). This is not yet fully achieved, but programming languages like Python and script converters like ChatGpt or Claude have already started this process. Indeed, even for someone with basic programming knowledge like mine—I only independently read the book *Automate the Boring Stuff with Python*, by Al Sweigart, for 2 months—simply by using ChatGpt as a language translator from English to “python-ish”, I was able to create a useful application. My app quickly checks and draws different cross sections of reinforced concrete beams and presents the solutions as images. Beyond the difficulties of communicating with the computer, the way the computer receives commands is straightforward:

“Do this, and then do this.”

“If these conditions are met, do this; otherwise, do this.”

“Do this. Repeat this 40 times.”

“As long as this is true, keep repeating that process.”

Peter Debney, reflecting on whether calculations still hold the same value in contemporary structural design, recalls a 2003 New Civil Engineer survey that asked practicing engineers if a math “A” level remained essential. The results were mixed, though everyone agreed that mathematics is highly useful. He notes that modern engineers no longer need to be expert mathematicians like their predecessors, since computers now perform calculations far more efficiently. Instead, the practical mathematical skill required today is largely the ability to ensure that the correct inputs are provided. [6]

If you ask any engineer today, they will tell you that mathematics is very important. Yet, the design processes now involve very little applied mathematics by the designer. The reason why structural designers value mathematics is that, firstly, they come from a time when it was really important to them, and secondly, they have been constantly warned about the potential and limitations of computers. Therefore, they have naturally developed a skeptical

approach to computers. With the change of generations, this will no longer be possible. Computers do exactly what you tell them to do. Whether the so-called AI have intelligence or not is debatable and will be explored in the next subchapters, but the fact is that the way a computer does calculations is different from the way a human does calculations. People take short cuts, while computers will calculate everything, every time. In the early years of computer creation, if you had to perform a structural analysis with a program, you had to build the code yourself. Most engineers now rely on black box software where only the inputs, outputs and interfaces are visible and everything else is processed by the computer in secret. In recent years the tides have turned and designers have started coding programs again. Even black box software, through code editors, have made it possible to create bridges where designers can benefit and intervene by adding processes to these software that they were not originally programmed to do. API³ paths have also made it possible for different software to interact with each other by creating automatic design processes that involve several software at the same time. For example, today structural designers can use FEA software to model the structure, then automatically export the results to Excel, then analyze them and manage data automatically and calculate reinforcement and sections of structural elements with Python, then automatically make structural design drawings with Grasshopper. An additional Python script does data transfers from one software to another automatically, while another program works in the background to validate the codes. We are also seeing the increasing use of Machine Learning and Artificial Intelligence in structural design. While it cannot be said that these innovations will create better structures, what is evident is that they have made the design work more efficient. My skepticism is actually related to the limits of computers to grasp reality, in the words of Peter Debney for a simple example; "but such a program would still not be able to attend a client or site meeting." [6] He continues by noting that the distinctive qualities of engineers lie in their capacity for inventive problem-solving, while computers excel in speed and calculation. He argues that the most effective engineers exploit this complementarity by drawing on computational power to refine solutions, test design variations, adapt rapidly to new conditions, and reduce unnecessary repetition. [6]

Programs can give us the freedom to focus on the most important things, but at the same time, they can stifle us. We need to understand their potential so that we know their advantages and disadvantages so that we can use them to their best advantage. In the words of my university professors, "Total freedom means a blank page where anything can happen, but usually nothing happens, because there are more possibilities than there should be." By the same logic, something that has infinite limitations is insoluble. Life does not flourish in total order, nor in total chaos, but in a delicate balance between the two. To make structures we need a balance between desires and constraints. The previous skills that a classical structural designer needed are mathematics, physics, calculations, statics and dynamics. The

³ Application Programming Interface is any bridge that connects different computers or software.

skills that a designer needs today are much more complex. Mathematics is still an important tool in design, but instead of the designer doing the work, the computer now does it, and the designer has taken on the role of a controller of this process. Automation is clearly one of the values of design in our Zeitgeist, but it is not the only value, since not all processes are mechanical. Craftsmen in the Middle Ages worked with rules of ratios of structural proportions, and used the tools of the compass and ruler to build gigantic works such as cathedrals. Later, during the Industrial Revolution, structural designers built bridges, tunnels, the Eiffel Tower, etc., using slide rules and drawing boards. With the improvement of tools and the transition to calculators and computers, designers built even more complex works such as the Burj Khalifa or the Louvre Abu Dhabi.



Figure 60 - Louvre Abu Dhabi (author, 2024)

Creating automated processes is time-consuming, so the time spent on it should not exceed the time saved later. If only one model is enough for the structure you want to create, then you can model it with a classic FEA software. But if you need to find the best solution from a million different variants, then you will need to build a script for the geometry and analysis

of the structure, specifying the parameters that you think should be variable to make it possible to explore different versions. Parameterization is all about change. Unlike modeling, it takes computer-aided design to another level, being concerned with building a variable state of the model and its characteristics, rather than simply building it on the computer. Just because it is a variable state, it does not mean it has to be a chaotic state. The structural designer must continue to be in control of the modeling and, in this case, must build a script being sure that for any of its variants, it gives a decent model.

This brings up a dilemma: in all modeling programs you have the option of working with programs that you can modify yourself or change certain processes, or to accept their default state, which is usually supported by best practices and design codes. In the first case, the problem is that you need additional work to put together all the conditions that come from the design codes or to take into account various basic problems that in the case of structural design are not so simple. On the other hand, the good thing about this is that you will be in full control of what the program does while also building the script for that exact project and its problems.

When building a program for structural design, the most important thing is not to forget the purpose of why you are doing it. Modeling a beam, for example, changes a lot, if it is built with CAD, BIM, FEA, or spreadsheet software. In CAD, the only important thing to consider is the abstraction of the beam and its conversion into a geometry. In BIM, the model will add geometric and qualitative data such as volume, weight, material, etc. In FEA software, the same beam will require the characteristics of the modulus of elasticity, yield stress, etc. In spreadsheets, for the calculations of The Bill of Quantities and its construction cost, for example, the geometry of the beam will not need to be considered at all, but only information on the volume, the hours of work to build it and its cost/unit.

Then, if parametric logic is used, it is impossible to describe exactly what characteristics will need to be set for this beam. This is in fact what separates a computational structural designer from his colleagues. His work on the computer does not have a manual. He only has the tools in his hands and it is up to him “to reach the stars”. Indeed, computational programs are open-end, in the sense that every day new plugins are released by their users, who build design programs according to their needs and at the same time improve the work on a global scale by making these programs accessible to their colleagues around the world. These tools are automating the design processes. Now AI, Machine Learning, optimization, cloud and quantum computing promise to take structural design to other levels by managing situations much more complex than the capacity of today's programs can handle. The profession of structural design has entered a phase of reform. The Industrial Revolution gave us cast iron, steel and steam power. The 20th century introduced us to reinforced concrete, nuclear energy and computers. There is no reason not to believe that the 21st century will not be revolutionary.

At this point, it does not hurt to imagine a little. Debney, for example, envisions a future where maintenance robots with magnetic feet move across long-span bridges, removing corrosion and peeling paint before spraying on new metal to repair weak points. [6] He imagines coatings infused with stress-sensing fibers that can transmit data on strain and cracking, and structural elements no longer confined to prismatic beams but optimized along their entire length. In this vision, structures are not fabricated in conventional ways but printed, with costs determined by material usage rather than manufacturing. [6]

"Anything that can be automated, will be." (Betancourt, 2013) [99]

Nevertheless, the task of a computational structural designer is essentially no different from that of his colleagues thousands of years ago. His task is to improve people's lives by designing structures for them. His task is to find the best answer to this question in each case, but it is also terribly important to find what the right questions are in those cases. The so-called AI, for example, is very good at answering questions, but it has a very hard time answering questions that have not been asked before. Moreover, it is up to the designer to ask the right questions. The so-called AI is a machine, which means that it cannot give you good answers as long as it asks the wrong questions—or to put it another way in the words of programmers: "Garbage in—Garbage out". The so-called AI promises—and it is likely that this will happen very soon—to work as a digital assistant for structural design. The structural designer of the future could be a high technologist, who codes and controls digital tools, which perform all the design processes. However, he could also be a structural artist or a structural phenomenologist, or a structural socialist, or all of these together. To the question "Will the so-called AI replace current professions?", we can answer "certainly the professions are the ones that will adapt and change themselves" or to put it differently, in the words of my boss who does not forget to remind us every day; "Adapt or perish".

In all this confusion and the beats of time that have gripped the professions, it seems that there is hope for the future. It seems that everyone is of the opinion that the so-called AI will not replace humans, it will simply elevate them to higher levels of thinking to deal with "art and poetry" while the computer does their dirty work.

Computer automation relies on programming languages that provide instructions that can be executed by the computer through step-by-step procedures called algorithms. As already mentioned, an algorithm is a procedure that serves to answer a question through a finite list or well-defined instructions. The strategy for creating an algorithm is to divide the problem you have into smaller and simpler steps that can be calculated.

Despite being closely related to computers, algorithms can also be found in reality. For example, a recipe can be considered an algorithm as long as it is well-defined, as in the following case:

- Step 1: Gather ingredients: spaghetti, tomatoes, garlic, olive oil, salt, basil;
- Step 2: Fill a pot with water and bring it to boil;
- Step 3: Drop spaghetti into boiling water and stir occasionally until cooked “al dente”;
- Step 4: While spaghetti cooks:
- a. Heat olive oil in a pan;
 - b. Add chopped garlic, heat until they have a gold color;
 - c. Add tomatoes; simmer the ingredients inside the pan until sauce thickens;
 - d. Add a little salt and basil.
- Step 5: Remove spaghetti from water;
- Step 6: Mix spaghetti with sauce in a pan;
- Step 7: Serve a plate of hot spaghetti.

However, computers would still not understand this algorithm, since computers want everything specified very clearly. For example, the computer would probably want to know the heating time and how many degrees it will heat it and what will be the upper and lower limit of the allowed temperature, how many grams of salt it will add, how it will put the pasta on a plate and how many grams it will be, etc. Without well-defined instructions, the algorithm in the computer is prone to failure.

As for the inputs, they can be of different nature and contain different sets of values. There are inputs, such as “Boolean values”, which contain only two values: the value “true”, and the value “false”. There are inputs consisting of segments of numbers (temperature from 80°C to 120°C) or even set of numbers with a fixed order (for example, only even numbers from 4 to 12), or texts, geometries, etc. An algorithm generates a well-defined output. If something has gone wrong with the algorithm's workflow—let's say the user has entered text instead of numbers in a parameter—the output will generate error messages and warnings.

Algorithms are at the core of computers and their nature and capabilities define the former. By using these tools on the computer, there is no need for us to be active during computer processes and order the computer to perform an action by typing or clicking with the mouse somewhere, but the computer itself can initiate and continue its tasks, after you have initially given the instructions through an algorithm.

This idea, which in professional language is called scripting, is the method that computational designers follow during their work. Scripting contains two interfaces; the editor page where the algorithm is written and the model page where it is displayed. Software such as Grasshopper and Dynamo allow users to construct complex geometries by making them dependent on initial parameters, which are also selected by the user. The advantage of visual programming is that the coder can see changes in the geometry of the structure in real time, while working to build the algorithm. This allows him to gain an intuitive ability, to

interact with the computer in the same way that a craftsman interacts with a hammer while carving a stone.

The parametric workflow that the designer builds on the coding page is in fact a smart medium for structural design because it enables an internal self-consistency translated into a graphical language that can be managed very easily, allowing designers to explore different forms.

For example, through this approach we can solve multi-objective optimization problems in structural design. Such a problem might be: “what are the best spans for a certain structure to maximize structural performance and minimize construction cost, while satisfying stability and spatial constraints?” (fig.61).

Linking Wallacei (a multi-objective optimization tool) with Swallow (a parametric tool that bridges Grasshopper with Etabs) and Etabs (a FEA software made explicitly for structural design); I am not simply pursuing a single “optimal” answer. I am in fact exploring a range of high-performing alternatives. Each solution option that the program offers is an optimal solution in itself, but it balances a trade-off between the two objectives and it is up to the designer to choose between these options. This process highlights how computational methods do not just serve to provide a generic solution, but to provide alternatives to choose from and to further involve the designer in decision-making.

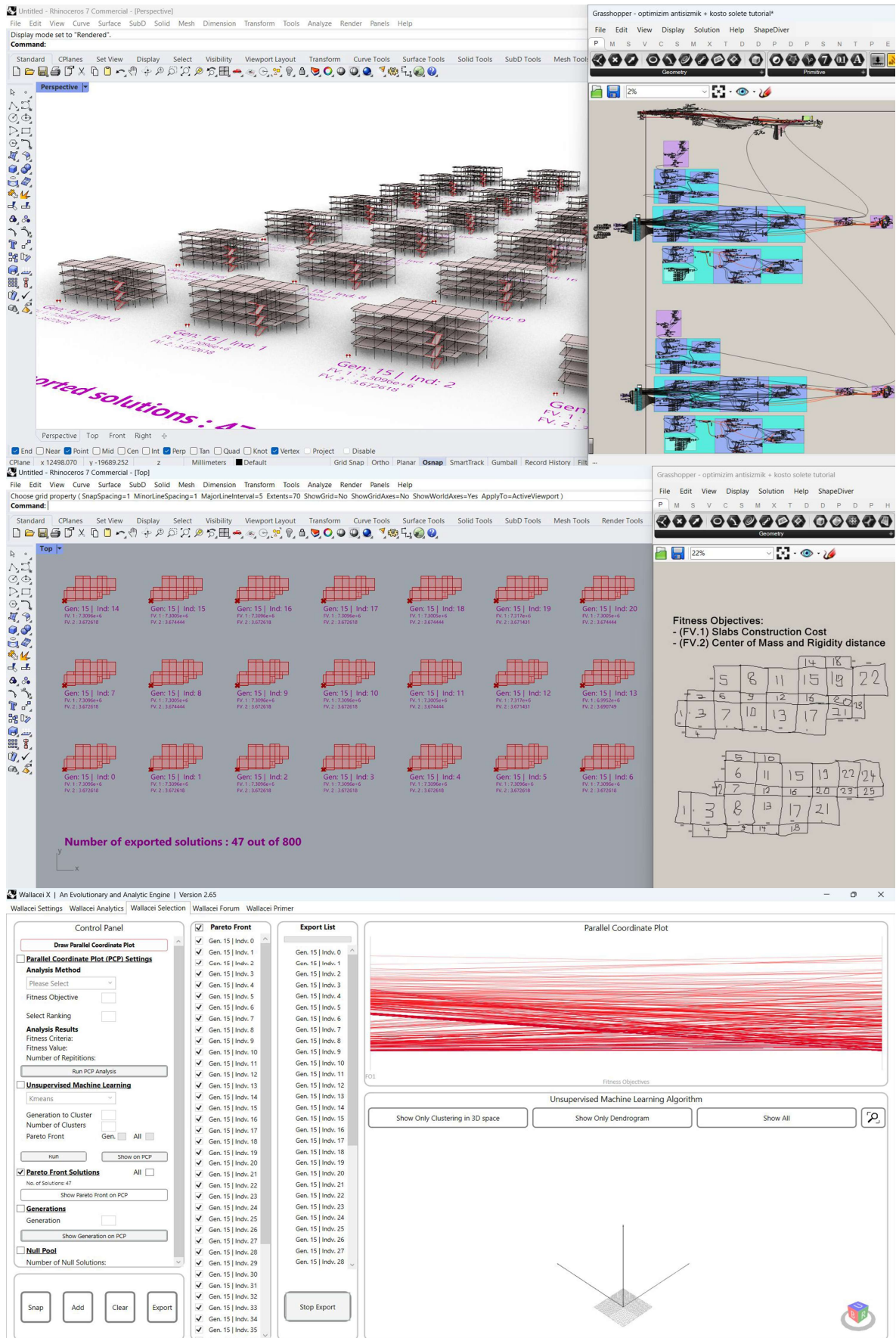


Figure 61 - Computational structural design project made by the author

On the other hand, there is a superficial overproduction of forms based on computational design that have been encouraged by the ease of providing such programs to produce certain forms. This should not demotivate us, but, on the contrary, it shows once again that we must wake up to carry out our task as structural designers with all our potential. The creative process of design can be filled with the use of computational tools, but they do not have to replace—and cannot replace—the role of the creative mind. The misunderstanding of generative systems as automatic processes independent of humans is the main reason why critics have attacked this methodology. Rightly, if the process were completely automatic and generative, design would lose its cultural values and especially its ambiguity, complexity and contradiction. However, I always believe that there can be hybrid solutions where the processes are divided into a balance between computers and the human touch.

Arturo Tedeschi points out that redefining the designer's role also highlights the difference between the designer and the technical virtuoso. [79] Though both bring distinct strengths, one does not necessarily imply the other, and the distinction remains as relevant as ever. Shared understanding and knowledge exchange are important, but the two roles do not always overlap. Code-based design, in particular, requires a rigorous logical and mathematical foundation, while today's designer must be able to grasp its setup and underlying rules in order to engage with it effectively. [79]

Although it is true that a structural designer cannot do everything, the division between professions is not as explicit as Tedeschi claims. What is actually happening is a reformation of structural engineering and structural design, which, thanks to the great advancement of the computer, is returning to its origins. Structural engineers and architects participated in the creation of the first computers and later pushed forward research into digitalization—Konrad Zuse, Ove Arup, Nicholas Negroponte, Cecil Balmond are some of them. An engineer—by definition “ingenious”—is someone who solve problems in a clever way. Meanwhile design, as we have already seen, is a social human activity and not necessarily a mere problem-solving act. Which means that, just sticking to the original definitions, engineers will be the ones who will produce structural programs to help structural designers and to enable the latter to deal with the social and technical aspects of designing structural forms. This argument is also supported by the concern raised by specialists in the field of computer science when they say that their profession will merge with all other fields. As a result, in the future it will not be enough to just be a programmer, but a programmer who has deep knowledge of a certain aspect of life—such as structures—will be needed.

4.2 What Computing Really Do

Late modernists have a much more powerful tool than photography or balsa models for erasing time from design. The computer brings about the distancing of structure from the temporality of the world from the very beginning of the design process. Its power bewilders designers and later viewers—such as clients or work teams—and makes them believe that what they are seeing on the screen will be achieved on site. The mirage increases even more when the computer, by allowing objects to be moved or passed through, creates the fictitious idea of time, giving life to solid geometric figures. However, for Till, this representation of time is “no more than an extreme form of temporal coercion”. [8] The problem with this case is that it does not present time with the diversity that characterizes it, but as an itinerary that comes from the reduction of time to a linear viewpoint. When Laurie Anderson said that she would not trust virtual reality until they learned how to put dirt inside it, this does not mean that we should rush to make images look as real as possible. [8] On the contrary, Anderson's message is about the lack of time in simulation. The more real the image seems inside the computer, the more it distorts the notion of time by petrifying its flux. The movement of the sun is reduced to a play of light and shadow, the influence of the weather reduces to changes in the colors of the background, the vibrations of the earthquake to some mode of deflections of the geometry of the structure, etc. As a representative of reality, one effect that accompanies the confusion, which the computer causes, is that it reinforces the autonomy of the structure as an object. By falsifying time inside the simulation and claiming that the object of the structure is there, structural designers have the luxury of dealing only with geometrical form, unconcerned by social flux and real time in reality. Simulation drains the structure's life, and in the words of Gordon Matta-Clark, “when a thing does not have any life at all, it seems to have a lot of manipulation for manipulation's sake.” [8] If we remove time from structures, there is nothing left but to play with geometry and technical aspects, as if structures are not part of life.

Another thing that withers in the digital world is the aura of the work. The technique of reproduction separates the reproduced object from the domain of tradition. In the words of Walter Benjamin, he explains that reproduction replaces the singularity of an original with multiple copies and allows audiences to encounter works in their own contexts. He concludes: “...these two processes lead to a tremendous shattering of tradition, which is the obverse of the contemporary crisis and renewal of mankind” [100] Both processes are closely linked to the use of simulations. Over long historical periods, the way of perception of human senses has changed not only due to natural causes, but also due to the way in which society and technology have advanced. Specifically, the power of the computer to bring things closer spatially and humanly, as well as the desire of modern society to have things close, to control them, has brought about a reduction in the aura of works. From this desire and from the impossibility of having things always close, modernity has made a pact with

the reproduction of things and has accepted them as if they were the original—for example, they equate images of the structure with the structure itself. However, the reproduction offered by simulation and images differs from the image of the structure seen by the unarmed eye.

Benjamin argues that reproduction strips objects of their aura, reflecting a mode of perception so committed to the “universal equality of things” that even singular works are reduced to sameness through mechanical replication. [100] Indeed, unique, individual experience is no longer as important as it once was, and perception is adjusted to the mass scale—through films, photographs, simulations, etc. This tendency of the modern spirit is also seen in the increasing reliance on statistical science to understand the world through numbers, averages, and mass data rather than the importance of individual experiences. As a result, reality is being reshaped for the masses. But the masses are also reshaped from this new reality, in the sense that people’s minds have adapted to simulations. From a computer, for example, one can make a certain number of sheets of the same structural design. Asking for the authenticity of these sheets makes no sense.

Sherry Turkle recalls her arrival at MIT in September 1977: “A colleague in civil engineering took me to lunch to give me the lay of the land. He jokingly told me that I had come at a good time but had missed a golden age: ‘This place is going to hell.’” [101] He [Turkle’s friend] explained that the decline, in his view, stemmed from students relying on calculators instead of slide rules. With slide rules, students needed to know how many decimal places gave a meaningful result, but calculators removed that act, leading to wildly inaccurate answers. He added that the calculator problem was minor compared to the growing use of computers in teaching. For him, scientists and engineers needed to have “numbers in their fingers”, since true science began with back-of-the-envelope calculations. He advised Turkle to watch closely for transformative changes that occur only once in a lifetime. [101]

On one level, the answer to the question of what simulation/computer does is simple: it wants, and even demands, immersion. The computer is usually seen as having only good intentions, as if it frees the human imagination and helps with work efficiency. However, in Pallasmaa’s words, “Computer imaging tends to flatten our magnificent, multi-sensory, simultaneous and synchronic capacities of imagination by turning the design process into a passive visual manipulation, a retinal journey.” [24] Unlike pencil and paper drawings, or the sketches we make when doing hand calculations, the computer creates a greater distance between the designer and the structure, as it requires you to enter its world and remove you from reality. In our imagination, structure is simultaneously in our hands and in our bodily experience. However, our peripheral vision integrates with space, while focused vision pushes us out of space, making us mere spectators. Our disinterested and unfocused gaze can actually give us new possibilities of vision and thought, uninfluenced by the eye’s desire for control and power. It is precisely the loss of focus that can free the eye from its

historically patriarchal dominance. In 1984, a professor of architecture at MIT argued that to use simulation properly, users must learn “to do” and “to doubt”. He believed that students did not have the capacity to question simulation because the demands of their technical mastery made it very difficult to distance themselves from simulations. However, he also believed that by the time professionals reached professional maturity, they would have both immersion and skepticism. However, as Sherry Turkle later puts it, “Things have not been so simple.” [101] Simulation makes itself desirable and difficult to question. It translates exact science, engineering, and design materials into compelling virtual objects that interact with the body and mind. Simulation demands immersion from us, and immersion makes it difficult to question simulation. [101] The more powerful our tools become, the harder it is to imagine a world without them. They can bring good, they can bring bad, but what is certain is that the world inside simulation influences the ethical, political and artistic aspects of life. Individuals become immersed in the beauty and coherence that simulation offers. In contrast, simulation does not aim to embrace the contradictions of life. On the contrary, for it, errors are fixable bugs.

At the university where I teach, I often see how architecture and civil engineering students deal with simulation. For some architecture students, programs like AutoCAD or Revit make theory come to life. One engineering student says; “I knew that the principles of statics were facts, but I didn’t know that they could solve real-life problems and that they were real.” However, when he saw the principles of statics put into context to solve problems in a structural model, he experienced them in a more direct way. He expressed a paradox that is actually common in design: the virtual makes things more real.

From the beginning of Project Athena—an initiative at MIT to explore and facilitate student-simulation behavior—architecture faculty noted that computer fluency comes at a price; for example, design programs seemed to entice students to do unnecessary repetitive work, to make changes for change’s sake. In turn, students admitted that the program kept them stuck to the point where they sometimes felt controlled by it. In her book *Simulation and its Discontents*, Turkle tells the experience of some of the students on Project Athena. One of them says: “It is easy to let the simulation manipulate you instead of the other way around.” [101] Another student says that the program’s default package severely limited her imagination. When she drew by hand, she had a set of other preferred solutions that she used in her designs. Yet, when she used the default package that the program offered, it seemed to take her away from the first solutions she had in mind. In addition, when she selected the project with the help of the default package and abandoned the solutions before using the program, she felt as if the project was no longer hers. She also noted that the solutions that the program offered were the easiest to implement. She says: “To get to the default you just have to hit return. It makes me feel too secure. If you use the default, it is as though the computer is telling you, ‘this is right.’” [101] Another student says: “Why would [the default solution] be in the computer if it wasn’t a good solution?” [101] The default solutions offered

by the software provide a sense of validation, a kind of design manual, with which designers can close the design phase directly and avoid headaches.

Ted Randall, professor and urban planning expert, emphasizes the personal connection we have with our own creations. “You love things that are your own marks. In some primitive way, marks are marks... I can lose this piece of paper in the street and if [a day later] I walk on the street and see it, I’ll know that I drew it.” [101] By contrast, he suggests that with computer drawings the sense of ownership is weaker: “People do analyses of their plan [on the computer] but they only fall in love with the marks they make themselves.” [101] What Randall is trying to say is that there will always be something in reality that neither simulation nor computer in general can contain. The versions of reality presented on the screen will always be incomplete and yet they will seem to represent the full reality. We accept them as they claim to be, because they are compelling, but that does not make them less fake than a pair of Abibas shoes. We accept them as full reality because we have them. We have them in our homes, every day, just a click away, and we are content with them. So, even though we have every reason to doubt the truth in virtual reality, we tend to use them anyway as if they were reality itself. As Randal later puts it, his students have already embraced this alliance with simulations. They are no longer interested in questioning what is on the screen, and this tendency has been aided by the lack of transparency of the programs used for computer-aided-design. In fact, programs brag about precisely for the clarity of the simulations they offer. But this clarity, as we have seen before, does not mean that it makes the design more real. On the contrary, the real design, reality itself, is ambiguous, and the tendency of programs to erase ambiguity altogether paradoxically makes them opaque.

Despite the hopes that the university of MIT had at the beginning, that students would learn to code and become experts at deconstructing and managing the code of the programs they worked with, most of them ended up working with systems that they did not understand how they were implemented at all. If a tool is a black box, it is impossible to do verifications yourself. Consequently, students and later design experts had no choice but to trust the simulation, which meant that they had to trust the programmers who had written that program and made that simulation possible. To challenge this problem, some designers believed that in order to design it was important to learn programming. In this way, they could understand how their tools were created and would know their limits and would finally learn to have a critical eye towards the computer and the simulation. There were also those designers who thought differently. Some argued that in the future creativity would no longer depend on understanding the tools they were working with, but on using them wisely. That is, the less you used them and the less you had to deal with the technicalities of coding the software, the more time you would have to deal with other aspects of design. They saw coding and design as two opposite sides; for them, simply acquiring technical coding skills was enough to negatively affect design. By the mid-1980s, with the introduction of the program Growltiger, it became possible for civil engineers to create a visual model of their

structures. Furthermore, through it, various elements of the model could be modified or removed, and engineers could see the consequences that this had on the structural models. For engineering students, this program was very useful because it relieved them of dozens of calculations. They used it to test theories, to design using intuition, and to explore different forms. However, very quickly, as with computer-aided-design software, the enthusiasm faded and turned into doubts about what the software would take back from design. Above all, the fear was that the clarity and simplicity that this software offered would lead engineers to overlook important things and make serious mistakes. Just as drawing remained a sacred place for architects, engineers considered structural analysis the same and they refused to use simulations for it. As Turkle explains, shortly after these programs were released, a sense of denial gripped engineering faculties. [101] In her book she tells the story of a professor at the time, who worriedly mentioned how his students, when using simulations, not only did not put their sense of judgment into practice, but they did not even bother to learn the capabilities of the program. Thus, they were producing very bad results. [101] However, at the beginning one of the main reasons for the high criticism of the programs was their fragility. The programs crashed, work was delayed, data was lost, etc. Then, little by little, the programs became better and students and professionals who were skeptical at first were learning to live simulation as if it were reality. From a total rejection of the use of software to analyze structures, the new paradigm said “structures could be analyzed by computer, but at least the results obtained had to be validated once through manual calculations”. However, as Turkle points out, contrary to faculty expectations, some students embraced computer-aided-design programs to draw and Growltiger to analyze structures with a bottom-up approach, entering the world of simulation and exploring new solutions that would not have been possible without it.

“A great musician plays himself rather than the instrument, and a skillful soccer player plays the entity of himself, the other players and the internalized and embodied field, instead of merely kicking the ball”, [24] writes Pallasmaa.

Similarly, in the design process, the structural designer gradually perceives the context, functional and structural requirements, movement, balance, and real scale of the structure through his or her body. While the imagined structure comes from the interaction of the designer’s body with the surrounding reality, the product reflects this bodily sensation. As a result, the product is in fact a communication between the body of the structural designer and the bodies of the people who encounter the structure throughout their life. To understand structural scale, for example, is to unconsciously measure the object or building with your body, and to project your body within that space. When our imagination, based on the perception of the structure against our body, gives us the green light to move forward with the project, we are overcome with a sense of peace and are comfortable with that solution.

Indeed, from the students' point of view, the programs allowed them to take an element of the design and play with it, allowing them to move from one idea to another. In simulation, design did not require precise plans. You could play with the solutions like a sculptor plays with his work. You could interact with the simulation and use its potential to evolve your ideas—or the simulation's ideas. This approach to the simulation as something with a life of its own made it easier for students to navigate it, to discover what it had to offer. Turkle explains this change very well by implying that originally, computers were introduced as tools for top-down calculation, but they soon revealed themselves as enablers of bottom-up exploration. Designers expected them mainly to accelerate work and eliminate repetitive number-crunching. What they had not foreseen was that computers would open up entirely new perspectives on sites and structures, as if crossing into another dimension. [101]

When experiencing a structure, we unconsciously mimic its configuration with our bones and muscles: the pleasantly animated flow of a piece of music is subconsciously transformed into bodily sensations, the composition of an abstract painting is experienced as tensions in the muscular system, and the structures of a building are unconsciously imitated and understood through the skeletal system. Unknowingly, we perform the task of the column or of the vault with our body. (Pallasmaa, 2005) [24]

Architects of the 70s and 80s wanted to protect the methodology of drawings for the design of buildings, which they saw as an essential tool for the creativity and authenticity of their works. Civil engineers wanted to preserve manual calculations at all costs because without them, they worried that structural designers would be blinded and would be faced with great uncertainties, which would lead to major errors. Their generation felt compromised by simulations, especially when they were “black boxes”. Their use was for designers of the 80s an abdication of professional responsibilities. For the new generation, computational transparency, in the sense of what the generations of the 70s and 80s considered, is something that belongs to the past. Transparency once meant being able to decipher the codes with which the program was built. Now, with the new sense of transparency that the Macintosh promoted in the 1990s, which seems to be part of computer culture, it means quite the opposite: being able to use software without knowing how it is built or how it works. Moreover, contrary to the hopes of the professors in the Athena project, time has shown that simulation influences even highly skilled people. Consider surgeons, who now undertake complicated operations through virtual simulations, moving 3D anatomical models with the same hand motions that they used to manipulate cadavers or plastic organs. When the body is involved in the simulation, doubting it becomes very difficult, because doubting the simulation then begins to seem like doubting your senses and perceptions. As for the influence of default program pre-sets, time has shown that even in this case, it has affected even people with high expertise. Writing about the professional life of some designers in the 2000s, Turkle notes Marshall Tomlin’s concern that he often feels pressured to accept the “default” choices offered by the system rather than asserting his own authorship. This leaves

him wishing his work felt more personal, while also worrying that his drawings may be misleading. He explains that when renderings were hand-drawn, detailed plans represented a genuine commitment to a design direction. Now, however, he finds himself adding details to drawings that appear final even as engineers are still working out the underlying geometry. For Tomlin, the fundamental change is that buildings now look as though every detail has already been fully resolved. [101]

In 2024, an architecture student says that, while using parametric programs, he seems to have lost “references” outside of his scripts and digital models. “The thing is, scripts don’t have a user manual, they don’t have a second copy somewhere else”, he says, “which means you can never know if what you’re doing is wrong or not.” The scripts he created in the Structural Analysis and Computational Design course are for optimizing the seismic performance of structures. According to him, simulation mesmerizes; so much so that its potential sometimes seems incredible. Without a direction and without going to a previously followed methodology, the student is disheartened. In addition, “it’s all fun and games” until he is faced with the responsibility of defending his work. He has no way of proving that his script works 100%. Moreover, after the professors’ claims that Grasshopper is not a program intended for structural analysis, he leaves the script aside altogether and decides to make another model from scratch in a FEA software and perform the dynamic analysis with it, to be more certain. On the other hand, there are professionals like Jurgen, who has built and adapted the software he works with all by himself. For him, the fact that it is his program makes him so familiar that he does not need to think at all to orient himself in it. In a sense, he and the program have become one: he knows how to move the mouse and give instructions inside the program, to do what he wants to do, without thinking at all.

However, structural design methods today are generally based on black boxed software. APIs, the connecting bridges between programs and program windows where you can code, are still underused, despite the growing trend. Experts no longer talk about moving from physical models—mock-ups of structures—to models on computer screens. That ship has sailed. Instead, they are now concerned with moving through different virtual environments. They argue that intuition and creativity are essential skills when modeling using software, and they are concerned about the enthusiasm that young people have for creating with AI, considering them naive or accusing them of taking short cuts. A professor of mine, Luljeta Bozo, used to say: “Young designers today see everything new that comes out and say, ‘This is so much better than what we had before.’ Therefore, they throw away all the methods that worked before and embrace the new methods.” For senior designers, young people today are immersed in simulation like “drunk drivers”. These drunks have no sense of judgment about simulation. Turkle worries that when professionals can no longer understand what is happening inside the software, they will lose confidence in their project solutions, just as it happened to designers at MIT during the Athena project, forty years ago. [101] She observes that users who master only the surface level of programs often feel powerful, yet they remain

reliant on those with deeper expertise. This dependency creates a paradox in which power is accompanied by vulnerability, while the complexity of simulations makes their reliability difficult to verify. [101] In any case, regarding structural analysis of a structure, it is impossible to check every differential equation. To be sure, you have to solve all the equations of the finite element method. Even if you somehow manage to solve millions of systems of equations and find a solution, the hardest part comes after that: validation. In other words, you have to answer the question “Is this the solution you want for your project?” Which means that proof is not an option. In the meantime, the beautiful pictures of simulations continue to improve and persuade others—clients, architects, users, etc.—who are generally not qualified enough to question what the screen is showing. The screen in these cases may show a deformed structure, different colored strains—some very red, some blue—in different places of the model. No one pays attention, for example, to the scale with which the program undertakes these visualizations. The screen, when the structure and its renders go to the client, can present beautiful images that certainly affect him. “You can sell anything if you dress it up correctly... You can give a result which is complete ‘garbage’ but taken out of context, reviewers can’t tell the difference.” [101], says Charles. Meanwhile, in Turkle’s book, she notes how Griffin, another designer, says:

...you can make that fancy picture in two seconds. The program spits out pretty pictures and when you show that picture, people go, “Oh it’s all done!” And you can stand up there and say, “These are sort of the distances but don’t believe them. There are big error bars! It’s not finished yet! This is a rough idea!” And they’ll just hold on to it and go: “This is done because look how pretty it is.” So we now on purpose make ugly figures to show it’s not really done yet because they don’t listen to you when they see it with their eyes [laughter in the background]. You have to show them something ugly if you don’t want them to set on it and have it be the truth forever. (Turkle, 2009) [101]

Unfortunately, there are also designers who do the exact opposite. They use simulation to camouflage flaws so that the project looks feasible. “Let’s be honest, sexy images sell. A good portion of my work I based on being able to present a sexy picture.” [101], says Luft, another professional, and continues: “I was talking to a research sponsor who was at a research organization that shall remain unnamed. They told me that the next visualization that I gave them had to sparkle.” [101]

Over the years, simulation has introduced its seductive environment into all areas of life, and we are witnesses to our own seduction. Mechanical engineers have raised concerns about not falling prey to graphics in simulation. Luft says that beautiful code promotes the illusion of doing good work. When simulation pretends to be real, buildings appear completed without their project being finished yet, while scientists pretend there are no problems when they see molecules that appear only through the screen. The precision of the computer is mistakenly taken for perfection. Not only that, but the computer now also serves as a

guarantee of truth—a validation machine. However, simulation has another side to it: instead of seeking to replace reality, as many designers fear, simulation seeks to reflect reality. Unfortunately, what no one says is that simulations are never real. They are all wrong. Period. There is more entropy in reality than there is in the computer. Despite this fact, whenever there is a meeting somewhere in a design office, you can enter all the data of the month, or all the project renderings, including perhaps the monthly earnings and visualize it through a screen and the director will tell you that everything is going well. “When I say that all simulations are wrong, I do not mean that the results they produce are not close to the truth. What I mean is that they are incomplete results, they are not true.” [101], says Turkle. Dean Whitman, a biologist at MIT, insists that you have to produce errors with simulations in order to test it against reality, to understand that it is wrong. [102] If the simulation only shows you good things all the time, you will never understand how wrong a simulation is. Whitman, for example, states that the simulations of his scientific research are not presented by pretty images, but, instead, by uglier and more complex images. In this way, when faced with these images, they are more predisposed to find errors and continue the search. [102] Whitman also expresses the need to be vigilant about the limits of programs and to be open-minded to other possibilities that go beyond programs:

The scientist must always ask, “To what extent does a model limit us to iterations rather than opening our minds to new questions?” As a scientist, one must attend to what lies beyond any model: When you have a hammer, everything looks like a nail... So when you have either a model or a certain capability, and you come to work every day, or you start to write a proposal... you say to yourself, “Gee, what kind of crazy blue sky idea can I come up with today?” or “Gee, I think there are some more nails out there and maybe we should start hammering.” That’s the way I see it. It’s a trade-off in the lab how much of one or the other we do. (Whitman, 2003) [102]

The example below is about two colleagues in a design firm where one uses black box programs while the other knows how to code and has started to make his own programs.

Using only the black box program allows the first designer to feel more in control of the design process. He has known this program for 20 years and is familiar with it. For him, the program is transparent (in the Macintosh sense of the word), which is why he has never known nor asked to find out how the program he works with is built. However, from time to time new ideas arise to automate routine work processes, which they both agree on, since solving these problems saves a lot of time. As soon as the issue moves to coding, one could say that the entire project becomes the property of the second designer because only he is capable of managing such tasks. From the second designer's perspective, designers need to know how to code, because this will give them the opportunity to take the design to another level. He argues that the only reason designers avoid coding is because of the high level of difficulty and discipline required to learn it. The resistance of other colleagues to coding

during design reinforces his sense of being different and special. For others, programming is foreign to design. For him, it is the solution to all problems. Above all, he thinks it is a new way of doing design. His entire professional identity is built around his relationship with the computer. He was a student of the first designer. While the first designer taught him programs as a way to establish technical control over designs, for the second designer, programs, especially those that allow you to code, feel more artistic. For him, programs are a medium to manipulate the entire structural design process. For the senior designer, structural design programs are not artistic. Instead, he thinks that programs should focus on making structural designs technically correct. While they work, both designers are looking at the same screen, but they are not seeing the same thing. The senior designer has a working manual and a set of parameters predetermined by the black box program, which he modifies to build all aspects of the project. His former student has a more comprehensive and personal experience with the computer. In the words of Maurice Merleau-Ponty, “people incorporate instruments into their physical sensibilities through the experience of manipulating them.” [103] According to this perspective, the two designers have different experiences and consequently a different worldview of the model. The first designer is more detached, while the second is more embodied and internal.

Simply using a particular program embodies culturally specific views of virtual image making. Turkle says: “These [cultural values] will be transmitted to any user who engages with the program; that user will be drawn into the embrace not just of a specific program but of a way of encoding reality.” [101] William J. Mitchell, when he speaks of programs, calls them “frozen ideologies”. [101] Gary Downey describes the power of computer-aided-design as the subordination of design to simulation, which he sees as a process in which the designer’s eyes and hands are surrendered to the machine. [104] Michel Foucault similarly states that the program becomes another kind of power, a force that produces reality, “it produces domains of objects and rituals of truth.” [105] This is precisely the approach that the second designer—the one who knows how to code —refers to when he says that the computer is another way of seeing the world.

Computational tools now make it possible to produce results quickly and with impressive visual quality. While increased speed has its benefits, it can also reduce the depth of thought behind the work. In architecture and structural design, for example, programs like Archicad and Revit create models, run simulations, and even suggest optimized designs in a fraction of time. However, this often means that designers must work within predefined systems, and are only able to adjust parameters rather than redesign space and form from the ground up.

Feti Selmani illustrates this concern with the example of rope axial vibration analysis in Matlab. He notes that the “beautiful” diagrams and figures produced by simulations may be visually impressive, but they often conceal complexities like nonlinear behavior, material imperfections, and external disturbances. This creates a paradox: while computational tools

deliver quick and precise results, they can obscure the deeper realities of physical interactions within the actual system. The real danger, he warns, lies in users placing blind trust in these outputs, mistaking polished visuals for complete truth. [106]

This is why structural designers must rely on fundamental principles and intuition. Computation should serve as a tool for exploration, not as a substitute for critical thinking. The challenge today is precisely this; to find the balance in the use of computers, to exploit their speed and efficiency while preserving authentic, human-led creativity.

To find an ideal balance of the human-computer relationship, we can follow the phenomenological principles of human tool use. Henry Moore explains that the sculptor's task is to constantly engage with form in its full spatial wholeness. "He gets the solid shape, as it were, inside his head—he thinks of it, whatever its size, as if he were holding it completely enclosed in the hollow of his hand." [24] The sculptor mentally envisions a form from every angle, perceiving what lies on the unseen side while focusing on the visible one, aligning himself with its center of gravity, mass, and weight, and grasping both its volume and the space it displaces in the air. [24]

Dealing with any work implies an interaction through the body. The painter Graham Sutherland says: "In a sense the landscape painter must almost look at the landscape as if it were himself—himself as a human being." [24] From Cezanne's point of view, "the landscape thinks itself in me, and I am its consciousness." [24] A structure works as if it were a person, with whom the designer unconsciously converses. When we are faced with a structural work, we project our feelings and emotions onto it. In this way, an exchange occurs: we give the structure our emotions, while the structure gives us back its authority and aura. Eventually we meet ourselves in our work.

4.3 What Computers Can't Really Do

Computers are our attempts to give life to our concepts. Therefore, we can finally be God. But our concepts are not reality and we are men.

By following the steps of the philosopher Hubert Dreyfus, I can explain that what others call the common-sense knowledge problem of structural design is not really a problem about how to represent the knowledge of structures. In fact, it is the everyday common sense that allows us to experience what is relevant as we move through life, regardless of professional knowledge. Therefore, the task assigned to the so-called AI-software in structural design is overwhelming. What we are asking of them is to have an understanding of the world itself. However, in Dreyfus's words, "making our inarticulate, pre-conceptual background understanding of what it is like to be a human being explicit in a symbolic representation seems a hopeless task." [107]

An experienced structural designer does not follow the same steps for designing a form compared with the list he once followed when solving his first structure in university. To suppose that designers apply the same rules over and over while designing is the same as to believe that, since we once followed a certain catalogue of commands when we first modeled with CAD programs, we are now using an invisible catalogue of commands in our mind every time we model. In other words, the fact that someone relied on certain paths while acquiring a skill does not imply that those same guidances are relevant when that skill is used at a more advanced level. The more a structural designer experience design processes or gather informations about client needs, the easier it is to retrieve other important details about that specific structural design task. In stark contrast, structural design software would have to check everything from the beginning, following the same steps over and over and relying on their brute force and speed of calculations instead of insight. The more a software "knows" about a specific situation, the more difficult it finds to produce results. Moreover, by being masters of the cultural practice, structural designers can recognise if a certain procedure needs improvement or is not relevant anymore and can make changes in their methodology.

When we enter a living room, we do not list all its components, nor do we analyze its physical form. We do not begin to remind ourselves that the space has a floor, a terrace, or certain types of furnitures. Instead, we rely on the familiarity we have acquired by moving through a large number of interior spaces throughout our lives. This personal experience enables us to know almost immediately what is important in that situation and what is not. For example, as long as the living room is not ours, it rarely occurs to us to clean it, as long as we are not the janitor, or as long as our senses do not perceive signals beyond the ordinary (some food left on the table or dirty dishes in the kitchen). Even then, we do know from our human culture what the right thing to do is. We don't go to wash the dishes right away. In certain

cases we offer the house owner our help in cleaning the house, as long as we feel that he will not be embarrassed, but we can also leave immediately if the smell is pungent. Likewise, we don't consider windows at all except when we feel cold or hot.

A structural designer uses more or less the same method in his work. His experience gives him an intuitive sense of how structural elements will affect the whole designing process and how they can be combined together. He responds to the situation by drawing the structural form by focusing immediately on the data that is important, ignoring information that does not influence the task at hand. This ability does not come from the constant and continuous application of abstract rules, but comes from an ingrained sense of what is appropriate at a specific moment.

On the other hand, we humans find it very difficult to orient ourselves when we are initially faced with a situation that we have not experienced before, despite the fact that we may have previously created all the information about that situation. When we are in a courtroom for example, even though we know what to say and the environment is similar to the rooms we have visited dozens of times, we suddenly find ourselves stuttering and stressed. The difficulty of this situation comes from its importance and from the lack of experience we have in that situation.

Mark Johnson argues convincingly for the central role of imagination in conscious problem-solving. He explains that imagination provides the structuring activity that enables us to form coherent and unified representations, making experience intelligible and meaningful. From this, he concludes that imagination is fundamental to human rationality, shaping our ability to perceive connections, draw inferences, and solve problems. [108]

Great artists have always felt the truth, which is often stubbornly denied by philosophers, engineers, and technologists. The truth is that human intelligence cannot be isolated or understood explicitly. An Irish poet writes: "I have found what I wanted to put it in a phrase, I say, 'Man can embody the truth, but he cannot know it.'" [107]

For simple structural design problems, it is possible to simply keep trying all possible combinations until one of them stumbles on the answer. This trial-and-error search is another example of the brute-force that the computer carries—its ability to check many results very quickly. However, in problem solving, we need to deal with the systematic arrangement of data in order to navigate through it as efficiently as possible. This is where humans rely on their insight while computers run into trouble. If a problem is set up in a simple, predefined way, with a simple beginning and end, with predefined operations to move from one operation to another, then optimization methods can help us solve the problem by getting as close as possible to an efficient solution. This method works even if the solutions are not straightforward, since the solvers—as we will see in the next chapter—can find their own way to an optimal solution. But this methodology also contains many flaws.

George A. Miller in his writings—while mentioning George Pólya, who was a mathematician who wrote about the strategy of how to solve a problem—states:

In his popular text, *How to Solve It*, Polya distinguishes phases in the heuristic process: First, we must understand the problem. We have to see clearly what the data are, what conditions are imposed, and what the unknown thing is that we are searching for. Second, we must devise a plan that will guide the solution and connect the data to the unknown. (Miller, 1960) [109]

Then Miller completely underestimates the importance of the first phase, or simply decides to ignore it. He says, “Obviously, the second of these is most critical.” [109] He explains that the first involves forming a clear image of the situation to test possible solutions—a necessary step, but one assumed to be already completed when addressing well-defined problems. [109] He explains that a method devised for a simple problem can be extended as a strategy for tackling the original, more complex one. For instance, in propositional calculus, a machine might simplify the task by disregarding distinctions among logical connectives and the sequence of symbols. [109] Yet, all the psychological theory of problem solving in structural design would be of little value if the first step was not included in computer modeling. The distinction between essential and inessential is actually done by the human user himself, not by computers.

As for human insight, Dreyfus explains that we do not need to fully formalize patterns to distinguish them. He writes that a key sign of the difference between human and mechanical pattern recognition lies in the human (and animal) ability to tolerate variations in orientation, size, distortion, incompleteness, and background noise. [107] Early artificial intelligence attempted to handle this by normalizing a pattern and then testing it against templates. Humans, by contrast, tend to disregard such changes, perceiving a figure even when it is skewed, fragmented, enlarged, or reduced. While perceptual constants like size and brightness provide some degree of normalization, full smoothing is unnecessary, since recognition occurs alongside the acceptance of irregularities. [107]

Other newer programs, instead of normalizing patterns, rely on powerful operators to select discriminating traits, but still remain sensitive to distortion and noise. However, “old school” manual human design, when distinguishing patterns, does not seem to implement these artificial expedients either. In these special cases when a person can articulate their cues, Dreyfus states that “these turn out not to be powerful operators which include sloppy patterns and exclude noise, but rather a set of ideal traits which are only approximated in the specific instances of patterns recognized.” [107] Distorted patterns are not distinguished as falling into any lower level of traits, but “as exhibiting the same simple traits as the undistorted figures, along with certain accidental additions or omissions.” [107] By the same logic, noise is not tested and excluded, but in fact is simply ignored by people as unimportant.

Similarly, we recognize an object as similar to another object without having any characteristic that might be a necessary condition for arriving at this conclusion.

As Wittgenstein remarks: “A human mouth smiles only in a human face.” In such cases, the traits necessary for recognizing a resemblance (dancing eyes, mocking smile, etc.) cannot, even when thematized, be isolated and defined in a neutral, context-free way. Moreover, as in the case of linguistic disambiguation, the context in this example the whole face not only determines the features essential for recognition, but is reciprocally determined by them. The expression is not deduced from the traits; it is simply the organization of the eyes, the mouth, and so forth, just as a melody is made up of the very notes to which it gives their particular values. In this sort of resemblance, the notion of recognizing the pattern in terms of isolated traits makes no sense. (Dreyfus, 1992) [107]

Those who are able to recognize a member of their family, for example, do not need to make a list of predetermined traits that the other must have in common, nor is there any reason to suppose that such a thing is true. Indeed, to formalize family resemblances, in the sense of defining fixed identical characteristics, would mean to eliminate a kind of openness to new cases, which is the most striking feature of this form of recognition. Regardless of what list of traits is considered, a person can always create in his mind a fictitious family member who has similar traits to those he has considered, but without the need to have identical characteristics. To summarize, the most complete form of structural design must involve the combination of the three characteristics of general information processing discussed above: insight, fringe consciousness, and situational dependence. This process is implicit, meaning that information processing unfolds on the fringes of consciousness. Even separating the term “typical” from the term “generic” is difficult to do, and for Aron Gurwitsch these two terms are sometimes interchangeable. [110] In addition, as he defines it, the essential difference is that recognition of the general depends on implicit cues, which can always be made explicit. Whereas recognition of the typical, in the sense of what we were talking about above, depends on similarities that cannot be formalized. Consequently, recognition of the typical, unlike recognition of the generic, requires insightful ordering. [110]

Since recognition of patterns even of low complexity structures can require higher forms of information processing, today's AI—such as Midjourney, ChatGPT, etc.—struggles when it comes to duties of pattern recognition in design. These systems exhibit an impressive ability to generate human-like language, to respond to prompts with apparent understanding, and to produce visual patterns that are context-sensitive and mimic different artistic styles and compositions. Yet, even these powerful programs operate without genuine understanding, relying instead on vast datasets and probabilistic inference rather than the embodied, situated commonsense that characterizes human design.

In the digital age, it often happens that human processes are confused with computer processes. Allen Newell and Herbert Simon, for example, in one of their writings, note that “this approach makes no assumption that the ‘hardware’ of computers and brains are similar”, apart from recognizing that both function as general-purpose symbol manipulators and that computers can be programmed to carry out basic information processes comparable to those of the brain. [111]

Moreover, Geoffrey Hinton, during his Nobel Prize acceptance speech, says:

This year the Nobel committees in physics and chemistry have recognized the dramatic progress being made in a new form of artificial intelligence that uses artificial neural networks to learn how to solve difficult computational problems. This new form of AI excels at modeling human intuition rather than human reasoning. And it will enable us to create highly intelligent and knowledgeable assistants who will increase productivity in almost all industries. (Hinton, 2025) [112]

Then he goes on to warn of a deeper, long-term existential risk that may emerge once digital beings surpass human intelligence. He notes that it is uncertain whether humanity could remain in control, especially if profit-driven companies that neglect safety concerns develop such entities. “We urgently need research on how to prevent these new beings from wanting to take control. They are no longer science fiction.” [112]

These assumptions above are neither naive nor empty because they warn of apocalypse but fail to explain and ignore several questions that have not been answered for years and continue to be unanswered. What is a “general-purpose symbol-manipulating device”? What are these forms of AI allegedly shared by humans and computers? Since when did AI excel at modeling human intuition? We have seen so far how the requirements that a computer must meet to have human intelligence are, if not impossible, unattainable. It is not just about “unattainable” in the sense of the insufficiency of the power or speed of computers, but about deeply fundamental gaps between AI and “good old fashioned” human intelligence, such as insight, commonsense and pattern recognition. For the reasons mentioned above, there does not seem to be any evidence that the human mind works the same way as the computer mind.

The only way that Hinton's assumption about the possibility that computers will become as intelligent as us, and even surpass us—if not in all areas, at least in the field of structural design—is to meet at least one of the following criteria:

1. To meet the biological premise that brain neurons process information in discrete operations, somewhat resembling on and off switches;
2. To meet the assumption of the field of psychology that the human mind resembles a device that operates on bits of information according to formal rules. This assumption has also been encouraged by the terms used today, for example, “let me process it” is used instead of “let me think”, etc.
3. To meet the epistemological premise that all design processes can be formalized. In other words, to suppose that any structural design decision can be represented in inputs of “yes-es” and “no-es”.
4. To satisfy the assumption that the computational model of the design contains all the relevant information about the design. Which supposes that any relevant aspect of structural design can be represented in the same way or better by devices different from us and methods different from ours.

Biological premise:

Dreyfus challenges this assumption by writing: "even if the brain did function like a digital computer at some level, it would not necessarily provide encouragement for those working in AI." [107] He explains that the brain could instead resemble a vast network of randomly linked neurons, much like the perceptrons once outlined by early cyberneticists. [107] Programs can simulate neural nets in the same way they can simulate a structure, but such a program is in no sense a heuristic or creative design program. "Moreover it is an empirical question", [107], continues Dreyfus, "whether the elementary information processing in the brain can best be understood in terms of a digital model." [107] Indeed, the brain can “process” information in a completely different way from the way a digital computer does it. Dreyfus alludes: “Information might, for example, be processed globally the way a resistor analogue solves the problem of the minimal path through a network.” [107] This model is much more concerned with holistic problem solving, unlike the symbolic manipulation offered by the computer model.

In the 1950s, John von Neumann reflected on the human nervous system. “Now, speaking specifically of the human nervous system, this is an enormous mechanism at least 106 times larger than any artifact with which we are familiar and its activities are correspondingly varied and complex.” [107] He noted that its tasks include interpreting sensory input, regulating internal chemical levels, controlling motor activity, managing memory with intricate processes of transformation and retrieval, and transmitting coded signals and messages. While it is theoretically possible to approach such processes digitally, through

numerical coding and algebraic operations, the limited evidence available suggests that the nervous system in fact operates according to entirely different principles and methods. [113]

Consequently, even from an engineering perspective, the processes associated with human perception, action, memory, and by extension the activity of design—especially the complex judgment and intuition that structural design requires—appear to rely on principles different from those occurring within formal digital systems.

This is how Von Neumann explains what he calls “mixed character of living organism”:

The neuron transmits an impulse The nerve impulse seems in the main to be an all-or-none affair, comparable to a binary digit. Thus a digital element is evidently present, but it is equally evident that this is not the entire story. It is well known that there are various composite functional sequences in the organism which have to go through a variety of steps from the original stimulus to the ultimate effect—some of the steps being neural, that is, digital, and others humoral, that is, analog. (Von Neumann, 1956) [114]

However, even the description he gives is asking more than it is supposed to from the digital model. It does not take into account the other possibility, which in the words of Dreyfus, is "the nerve impulse is an all-or-none affair that any digital processing at all is taking place." [107]

He continues by clarifying that the distinction between digital and analogue computation is logical rather than dependent on hardware or electrical signals. In digital processing, each element corresponds to a symbol in a descriptive language and carries a discrete unit of information. By contrast, analogue computation uses continuous physical variables to represent information. The brain, which works through volleys of pulses, could be considered digital only if every pulse were linked to a symbol in an information-processing chain. If instead the relevant activity depends on the rate at which pulses are transmitted, then the brain functions as an analogue device—one that may resemble intuitive design processes rather than digital symbol manipulation. [107]

A help to understand more about this issue comes from Jerome Lettvin, who explains that it is actually the thickness of the axon of the brain that can play an important role in the way information is processed, working as a filter. [107] The filter that the axon makes possible allows the same neuron to fire at different frequencies. Moreover, axons can also change the characteristics of the filters depending on the signals that have recently passed through and the activity of the axons near them. If the effect of time and location plays such an important role then it seems that the arrangement of the brain is different from computers and neurons do not operate with on/off bits. [107]

Walter Rosenblith, one of the pioneers of computer use in neuropsychology, sums up the whole situation:

We no longer hold the earlier widespread belief that the so-called all-or-none law from nerve impulses makes it legitimate to think of relays as adequate models for neurons. In addition, we have become increasingly impressed with the interactions that take place among neurons: in some instances, a sequence of nerve impulses may reflect the activities of literally thousands of neurons in a finely graded manner. In a system whose numerous elements interact so strongly with each other, the functioning of the system is not necessarily best understood by proceeding on a neuron-by-neuron basis as if each had an independent personality Detailed comparisons of the organization of computer systems and brains would prove equally frustrating and inconclusive. (Rosenblith, 1951) [115]

Consequently, the claim that the brain operates as a computer is a hypothesis of the past that has never been proven. On the contrary, all the conclusions on this topic prove the opposite.

Premise from the field of psychology:

The theory assumed in this case is that there is a level of information processing in the mind that performs the same processes as a computer—compare, sort, list, merge, graft, flatten etc.—which produce intelligent behavior. This claim has gradually grown as a society belief and implies that processes such as design creativity, including structural design, can also be understood as interactions of procedures based on rules similar to those followed by a computer. This is in fact an assumption that people involved in AI—like Hinton—take for granted. Of course, while most believe that the brain is similar to a computer, the activities that the brain undertakes—such as thoughts or creativity—are also believed by most to follow the same processes as those followed by a computer when it operates. However, as we saw above, just because the brain is a physical thing that deals with managing information, it does not mean that it necessarily processes information like a computer. The same reasoning applies at the psychological level regarding the mind.

Dreyfus reasons in this way:

To say that the brain is necessarily going through a series of operations when it takes the texture gradient is as absurd as to say that the planets are necessarily solving differential equations when they stay in their orbits around the sun, or that a slide rule (an analogue computer) goes through the same steps when computing a square root as does a digital computer using the binary system to compute the same number. (Dreyfus, 1992) [107]

Likewise, the fact that we can describe aspects of structural form-finding or equilibrium in design terms via formal equations does not mean such design processes are themselves

carried out by discrete symbolic operations. The fact that we can describe processes from everyday life, such as reaching equilibrium, for example, in terms of equations and then break up these equations into discrete elements to solve them on the computer, does not show that equilibrium is actually achieved in discrete steps, nor that reality consists of discrete steps.

However, many AI enthusiasts, like Newell and Simon, want to believe otherwise, and ignore all the above problems. They say:

"There is a growing body of evidence that the elementary information processes used by the human brain in thinking are highly similar to a subset of the elementary information processes that are incorporated in the instruction codes of the present-day computers." [116]

What is this growing body of evidence? Have all protocol gaps been filled and exceptions made clear? So far not, and from the path that the development of AI has chosen, it seems as if it will never make progress to embrace human intelligence. The evidence that has emerged so far is based on the fact that there is an extremely large use of AI for solving everyday problems, but just because it is being used a lot, does not mean that its shortcomings will be solved by themselves. AI shortcomings are not errors, nor bugs, that would be solved by being identified and then taken into account. They are flaws related to the way the computer abstracts reality. To explain this absurdity, where the claim of those who deal with AI is that the evidence for the full achievement of human intelligence comes from the use of these tools, Dreyfus states:

Given the exceptions, the psychological assumption would have to already have been taken as independently justified, for the specific programs to be presented as established theories. Yet now the assumption is recognized as a hypothesis whose sole confirmation rests on the success of the specific programs. A hypothesis based on a methodological principle is often confirmed later by the facts. What is unusual and inadmissible is that, in this case, the hypothesis produces the evidence by which it is later confirmed. (Dreyfus, 1992) [107]

At this point it is no clear anymore why and how a set of instructions for a complete description in psychology should be formalized. On the one hand the claim that man is an object makes sense in some ways. The success of the modern project has been precisely this; to divide up human activities and give them scientific descriptions and then to feed these descriptions into a computer and simulate human behavior. These descriptions seem accurate at first glance, and since the time of the philosophers in Ancient Greece, man has always sought to describe physical objects in nature, by looking at them and noting their characteristics such as color, shape, etc. Unfortunately for psychologists, the physical description of objects is not a psychological description. That is to say, the mind, intentions, perceptions, etc. cannot be described in the same way that is followed to describe physical

objects. Nevertheless, without going into the definition of these concepts, if the premise—that our mind functions like the processes that a computer follows—is true, we will have to prove the existence of an intelligent machine. And based on the explanations I made above for the large gaps of artificial intelligence versus human intelligence, then the most plausible answer seems to be “It is not true”. Moreover, Dreyfus argues that human creativity cannot be fully accounted for by physical or experiential explanations, noting that “on the physical level we are confronted with continuously changing patterns of energy, and on the phenomenological level with objects in an already organized and meaningful field of experience.” [107]

Epistemological premise:

The epistemological premise differs slightly from the psychological premise. The difference is that, while the psychological premise believes that thought processes are produced in the same way as the actions that the computer takes when producing them, the epistemological premise argues as follows:

What if we accept that the mind and AI programs are not the same, but the method they produce to reason—the thought concepts—are actually the same?

This is in fact the premise that AI companies have as their target. Their claim is that a day will come when human thought concepts for all domains of life—including structural design—will be equal to the products of computer processing. In other words, this premise claims that the answers that AI will give us for structural design will be the same as those given by a qualified designer, no matter how different the humans are from machines.

Even if it were possible to simulate every possible situation, Hans-Joachim Bremermann has shown that even a computer the size of the Earth, running for the age of the Earth, cannot carry out all the calculations needed to simulate the complexity of human cognition. [117]

A machine encountering a new case must either fit it into its existing rules or guess blindly. Designers, in contrast, routinely adapt as they go, revising goals or forms in response to constraints that emerge mid-process. Computers must either fail and then be updated, or contain in advance the appropriate rules to handle the unexpected. However, the idea that one could pre-encode all possible exceptions and strategies for rule-breaking contradicts both logic and experience. No matter how many layers of rules are included, people can always find creative ways to go beyond them and still find meaning.

Ontological premise:

The last hope for AI to be accepted as genuine intelligence is the claim that, although AI processes and products are not the same as human ones, they can still be accepted as intelligent solutions by society over time. This is what Dreyfus had in mind when he raised the concern:

Man's nature is indeed so malleable that it may be on the point of changing again. If the computer paradigm becomes so strong that people begin to think of themselves as digital devices on the model of work in artificial intelligence, then, since for the reasons we have been rehearsing, machines cannot be like human beings, human beings may become progressively like machines. (Dreyfus, 1992) [107]

If Dreyfus is right and society is moving in that direction, then we are supposing that reality for a moment and hinting at what might happen. When everyone assume our knowledge of the world is knowledge of millions of discrete facts and everyone starts behaving as machines, the problem of artificial intelligence becomes the problem of storing and accessing a large database. The same model is assumed to be applicable to human creativity during design, using programs like Midjourney or Dalle-E to grasp “creative images”.

Marvin Minsky is among those who believe the above statement. Nevertheless, he argues that when we set aside specialized knowledge and look instead at the everyday structures needed for common sense, we find a complex collection of indispensable categories. These include the geometric and mechanical properties of space and objects, knowledge of how thousands of objects are used, facts about people in varying depth and scale, and facts about organizations. He notes that as one tries to classify all knowledge, categories grow quickly at first but soon become harder to expand. In his view, people rarely know vast amounts in great depth across many domains, which leads him to conclude that a machine would need roughly 100,000 well-organized elements of knowledge to function sensibly in ordinary situations, and perhaps around a million to reach a very high level of intelligence. If that estimate seems unconvincing, he adds, just multiply everything by ten. [118]

Therefore, regardless of accepting the assumption that we will start to design and create like machines, still the mechanical process of gathering countless discrete facts from artificial intelligence is very difficult. Minsky also warns that creating a universal system for classifying knowledge is extremely difficult, since even within a single field it takes enormous effort to build a workable thesaurus. Moreover, once a retrieval structure is in place, it often locks in assumptions that make it hard to add new concepts later. As he puts it, “It would be folly to base our intelligent machine upon some particular elaborate, thesaurus-like classification of knowledge... Surely that is no road to ‘general intelligence.’” [118]

For isolated activities, like a game of chess, AI programs work very well because the discrete facts are only within that domain. However, in the process of structural design, even a simple action like recognizing a structural design object—such as a bridge, a ramp, or even a slab floor, for example—requires understanding not only how the elements work, but also their role in patterns of life. The shape of the human body, the practice of sitting, the notion of structural design, constructability, comfort, form, and support are intertwined. These elements gain meaning in the context of human activity, not through enumeration. The domain grows even larger when you consider the communication part between designers and clients or contractors. In addition, the same situation can happen again, with other objects and people, just as the same objects and people can be perceived differently at different times. Which means that there can be as many different situations as there are different perspectives.

A concrete example is the situation of being at home. You can be at home when you are inside the building, but you can also be at home when you are in the backyard, without being physically inside the house. You can also be in the house, without being at “home”, for example, if you have not moved there yet to live. Being at home is a human situation, dependent on the social context, not on the object itself. Since there are infinitely many different situations and contexts which can also change infinitely since they depend on social aspects, not only on physical aspects, then their complete formalization is impossible.

How do us people solve these cases? Human beings seem to have another power; that of being inside the presence of time. In the words of Dreyfus, he argues that we do not process the world through fixed hierarchies of context; instead, each present situation grows out of the immediate past, shaped by what was just relevant. He writes, “Thus we carry over from the immediate past a set of anticipations based on what was relevant and important a moment ago. This carryover gives us certain predispositions as to what is worth noticing” [107]

4.4 Computational Structural Design Values

“I want Artificial Intelligence to wash my clothes and dishes, so that I can do art and writing, not Artificial Intelligence to do my art and writing, while I wash my clothes and dishes.” (Maciejewska, 2024) [119]

New trends in structural design have moved away from the understanding of form and performance, departing also from the connection with the material during design and during its production. In the words of Lorenzo Vianello, “The preoccupation of structural designers to reference and image design strategy has pushed the study of structures to the realm of ideological false hood that is removed from material and materiality.” [79] An image is not a form and is removed from the source of material that should be the foundation for design decisions. Materiality must be more than a reference for Young's modulus or mapping codes for renders. Structural designers must move beyond the production of images and connect with the materiality and information of material from the rich data of the world. Vianello continues his reasoning by suggesting that design must respond and be dynamically engaged with the information that shapes our world. [79]

Contemporary structural design practices have established a clear distinction between the role of the designer and the role of computers. According to this approach, designers are concerned with the form of the building and its functionality, while the task of the computer is to deal with mathematical “firmitas”. Further technological developments have mixed these two actors by having emerging shapes from its statics conditions, as well as creativity with structural calculations and it is about time to draw the line as to what are the values that the computer offers in structural design and what are the values that the designer offers.

Honestly, it seems as if computational design and heavy technology are far right, while heavy experiential design, telling stories, by being attuned with others and the environment, by embodied sensations, is far left. It seems that both no longer seek to provide reasonable solutions to serve people, but instead seek to increase their authority. That said, they are both extremists. They are two poles while the human is left alone in between.

Heavy based computational design seems to put design values in a basket and store them indefinitely, making any possibility of design freedom impossible while formalizing life. However, even the “lefts” have their faults. For example, Jeremy Till suggests designing by telling stories, and Alberto Pérez-Gómez suggests designing by being attuned while discussing stories. But what stories are you about to listen to and “to attune” when you are talking to clients? Because of their insecurities they will fail to explain their true intentions and will seek technological problem solving, which is consequently the same as doing classical computational design. This is at best. At worst, driven by quick profits, they will simply seek to maximize their gains. It is actually worse than doing classical computational

design, because they will look for unqualified design, looking for solutions that are deemed to fail from the start. Secondly, the key word is “unqualified”. It is true that people, belonging and situated in the world, have desires and dreams, which design must certainly take into account. However, design cannot rely only on dreams. It is heavily technical and requires professional knowledge. An unqualified design endangers the lives of people inside the structure to be designed. I reject precariousness for the sole reason that it goes against the values of humanity and against the ethics of construction. Which means that even the solutions offered by the “lefts” are not well grounded. If there is a way to proper structural design, it certainly must be a hybrid one. This does not mean that it has to be 50/50 left/right political ideology (nor 50/50 left/right brain approach). Nor does it mean that there has to be 50/50 participation approach. The designer must be a team leader. He must have the skills to negotiate as well as to invite and accept the ideas of others. He needs computational skills—which practically means having computer knowledge and exploiting the potential of the computer. He must also be able to attune with the environment and others. Both worlds give interesting ideas, but both worlds are contingent. Of course, mixing them makes another contingent activity, but this must be accepted and seen as an opportunity rather than a flaw. Finally, if there is a proper solution about design, it should be situational.

To see the algorithm run on a computer screen is to see a mad pixel explosion grow in scattered jumps. Without knowing where it is going, the patterns and overlapped sequences inject another intuition into the eye, of something unfolding, instead of images of static forms. A special dynamism beguiles the mind and previously unseen structures arise and evolve on the monitor screens. The digital model is of course an approximation of the initial model, which was imagined by the designer, but still the form can deviate from the initial preconceptions. At the heart of this interaction lies the question “when do the aesthetic eye and the algorithm converge?” How will the computer know when to stop and how does this relate to our preferences?

The next generation of software and hardware will allow the connection of complex forms with structural analysis, with 3D visualizations. There will be no need for analog systems and the search for project solutions can be entirely virtual. However, to deny a rigor of investigation of human touch would promote structural form only as a gesture of software. This would be dangerous, because in the end it would be meaningless. Somewhere a “pilot” must be placed to bring the solution home—that is, in our reality. To do this, the eye will have to observe the process and the mind will have to make decisions.

As Kasparov said, the centaur—a symbiotic form between man and computer—will be the best professional in life’s activities. [120] To do this, the structural designer must work in a symbiotic way with the computer. For this relationship to work, while working with the computer, the structural designer must acquire a critical eye, which as we saw in the previous subsections, cannot be achieved without first learning to code. It is important that designers

understand the scripts they work with and take part in the configuration of these scripts. It is important that, even if you do not build your own programs, at least you make them flexible according to your needs and make them an open book. Chatbots and the so-called AI help with this, not as deterministic, but rather as assistants and validators. Which means that, if the programs are full of errors, AI can fix these errors.

A sophisticated program can learn and optimize mechanical aspects of the structure such as the level of stresses, the level of loading of the structure, degrees of stability, earthquake performance, etc. Since the output will change constantly, because the code works in a loop, depending on the initial model, there will be no generation of same shapes twice. In other words, a spiral of generic solutions will be created that requires interpretation by the designer. All the designer has to do is specify an initial configuration that will direct the modeling process towards a series of dynamic transformations by the computer to meet certain objectives. These objectives are almost impossible to achieve without the help of the exploration of solutions that the computer enables. When the generation of the form is mathematical, all the necessary geometry and data are there to improve the “intelligence” of the model. For example, as long as the model has as its objective to reduce its overall weight, the computer can explore all the different solutions that satisfy the mechanical conditions of the structure and record the solution with the lightest weight compared to the others. In this case, the challenge lies in training the loop to learn and converge on starting points that lead to good conclusions. This means that before the optimization process even begins, an initial analysis will be needed by the designer to find a way to “optimize optimization”.

The starting point of the designer-computer relationship does not even begin with optimizing optimization, since this process, however much it requires intuition and insight from the designer, is merely a technicality compared to the carrying and deriving of the values that the initial model in the computer and the final structure in reality must have. The issue in this case is how to find these values, then how to turn the design values into design objectives that we can feed to the computer so it can manage them.

Not taking this process into account leads to what Pérez-Gómez calls “[structures] usually nonresponsive to cultural and natural contexts.” [58] Regarding this situation, he explains that since the nineteenth century, architectural space has been assumed to be fully representable through geometric systems such as descriptive geometry and axonometric projection, a logic that now extends into digital space via standard architectural software. As a result, the meaning of structure is often treated as something to be invented anew, shaped by the formal manipulations of the structural designer-artist and justified largely by novelty, surprise, or aesthetic appeal. When the physical context is considered in design, it is usually reduced to visual qualities, with the site imagined as an image or objective plan offering only limited formal or functional cues. [58]

The computational design assumption claims that objects generate their own meaning, which was justified by the self-evident permanence of structures compared to the ephemerality and volatility of the full reality. This assumption states that the structural designer should be concerned with technicalities while the architect is encouraged to abdicate his responsibilities of serving people. This situation is also fueled by a growing hedonism of misinterpretation of values as pleasures, which Pérez-Gómez claims that are taken from the architecture of previous periods, which failed to recognize anything apart from psychotropic tendencies in human development. To continue this argument, in the words of Pérez-Gómez, “Thus [regarding the modern project], comfort would become an exclusive objective: the avoidance of all painful conditions, an attitude already pointing toward a utopian dissolution of the human condition and obliterating the bittersweet space of desire that characterizes human existence.” [58]

Today’s parametric design strategies and other extrapolations based on “scientific” theories and tools that promise to formalize design processes are built on assumptions similar to those criticized to by Pérez-Gómez. The fixation with generative forms created entirely by the computer comes from our distrust of not being able to explain the qualities of experience that a given place gives us and by the lack of confidence that we may not be able to propose meaningful environments for human cultures. This distrust is also fueled by the fact that the things we experience are difficult to express in words, let alone by designing. The replacement of sensory experience with geometric spaces gradually led to the belief that the values of structures are the result of formal manipulations made by the structural designer in his office, and to the belief that creative solutions that solve technical problems will replace structural cultural richness. The failure to fulfill this paradigm has led to the field of construction being considered as an aspect without social values and as an activity to help the pockets of contractors, instead of being seen as an activity to help people.

Geometric spaces have their beginning with the development of the science of Descriptive Geometry, which became important for the discipline of construction from the 18th century and was then established as an entry requirement for architecture students in the 19th century. Despite our current familiarity with them, like anything new, in its early days, the concept of three-dimensional geometric spaces was unprecedented and a novelty for the time. Later, it became possible to control and dictate the production of any complex building, as well as to mechanize the design drafting process, without having to worry about the problem of translating the design process into the construction process, which had always troubled those involved in construction. From these developments, the paradigm of construction changed. Pérez-Gómez’s words regarding this change are striking:

The images produced by this method are no more than instrumental “signs”, and reality is consequently construed through the optics of the subjective observer. Indeed, a set of very serious contradictions emerges from the new imperative of reductive design

appropriate to a Cartesian, dualistic consciousness. Regardless of the ultimate intention, architectural space in effect appears as a production of the personal imagination, rather than a disclosure of place. Architects associated objectivity with orthogonal projections, their preferred mode of production resonant with the expectations of the new scientific culture; they now found perspective subjective, yet an essential tool for the presentation of ideas to the public (or a client), capable of provoking desired emotional responses. Perspectival renderings are increasingly used to demonstrate architecture's connection to the fine arts, emphasizing purely visual and compositional attributes as the values of so-called artistic buildings—structure as picture, as a consumable spectacle, of even greater value if signed by some well-known figure. (Pérez-Gómez, 2016) [58]

Nineteenth-century perspective and related artistic products demanded, in particular, optical accuracy, which later became photographic accuracy. It is important to note that the nineteenth century was the period in which not only the methods of perspective were discovered, but also isometry and axonometry. These methods became the accepted means of representation for a structural designer or even for an architect in general, producing design work that on paper (or on a computer) had its own authority. Consequently, conceptual spaces drawn in axonometry (or in plan or section) became representations of reality, assuming that the structure would have the same dimensions, angles, colors, and material characteristics as they did on paper. Axonometric drawings, plans and sections, through BIM programs, for example, allow designers to manipulate the shapes of models, thinking that they are manipulating the shapes of structures in reality. Yet, the problem is that the nature of the representation of these tools is entirely visual, so all our judgments while working with them are entirely “aesthetic” judgments, thus excluding the involvement of other senses and embodied dimensions of spatial experience. Merleau-Ponty explicitly examines how algorithms and the automatic solutions they offer comprise “a revolt against language in its existing state.” [121] Rejecting the contradictions and ambiguity of the everyday world, the algorithm—in Merleau-Ponty's words—is “an attempt to construct language according to the standard of truth, to redefine it to match the divine mind ... to tear speech out of history.” [121] Expanding his argument, he explains how the universality we desire from our world is possible only through the communication that nature has provided us with—through mother tongue, architecture, body signs, etc, which need not be ideal, in the sense of being entirely clear. This observation is especially important for all expressive activities, including structural design. Therefore, the attempts to generate numeric-bearing forms by reducing the values of reality to binary numbers on the screen also lose the values that structures are supposed to carry. Instead, Pérez-Gómez proposes that we cultivate an understanding of signs as carrying an inherent meaning—one that stems not from the abstract “I think” but from the embodied “I am able to”, tied to enactive consciousness. Language, as an “action at a distance” that gathers meanings without ever exhausting them, exemplifies corporeal intentionality, rooted in the pre-reflective layers of consciousness even as we

express discursive thought. [58] Therefore, for him, the simple interpretation we make of the world with that of basic communication is sufficient. The computer interpretation of our world interpretation—for example, the abstraction of form on the screen based on descriptions of reality—is what diverts the projection from reality. This spontaneous access that simple communication offers us—such as the body’s ability to perceive and do things, the “intentional transgression” that brings us closer to others, or even spoken language—cannot be brought under the jurisdiction of pancosmic consciousness without becoming meaningless again. In contrast to the model of modern project, the essential phenomenon of simple communication is the act of signifying and the signified, inseparable from each other. Considering the importance of simple communication, Pérez-Gómez suggests that projection should be understood within the context of a lived, physiognomic world, where structures—whether buildings, spaces, or temporary artifacts—serve as frames for human action and can be interpreted as a kind of gestural language. [58] “It is in terms of human language, its ambivalence and consubstantiality with our flesh, that we ‘understand’ all communicative acts.” [58] This designing approach does not hide contingency, but accepts it as it is. For only through contact with the designers and the environment can the environment speak back and give its messages. What seems contradictory or unclear in structural projects done with this approach is not at all a weakness to overcome. On the contrary, contingency is inherent in simple communication and, in the words of Pérez-Gómez, “[is] the price we must pay to have a conquering language which, instead of limiting itself to pronouncing what we already know, introduces us to new experiences” [58] It is the call that structure can never be ours alone, that simple communication destroys our prejudices. We would never see a new landscape or urban environment if our eyes did not give us reason to perceive, question, and create patterns of space that we have never designed before. On a more general scale, “We would not accomplish anything if our body did not enable us to leap over all the neural and muscular paths of locomotion in order to reach our projected goal.” [58], says Pérez-Gómez. Only in this way can design offer us new, previously unexplored worlds that help us solve the problems of our zeitgeist. Just as our bodies guide us through our daily lives without requiring us to try everything before we accept them or not, so too can structural forms and environments offer new possibilities only on the condition that we make common cause with them. Which means that there must come a point in design where we must stop examining the origins of the creation of environments and the logic of their future development. In this way, structures and environments are allowed to express themselves, through their own way, the meaning they carry. Ultimately, we should allow structure to speak in its own poetic, ambiguous, silent language. This form of communication cannot be possible by algorithms. Algorithmic design is triumphing as it carries with it the scientific logic that modern design and modern society promote. Algorithms are radically changing the world while poetry is being pushed aside as an illegitimate aspiration to knowledge. Instead of contributing together, these two forms of mediation of reality are placed at different poles. Merleau-Ponty reflects on this issue by

noting: "...algorithmic language (a language reduced to grammar) is in frank opposition to natural language." [121] From this tension, he argues, arises one of architecture's central dilemmas: while geometrical systems, despite their sophistication, cannot by themselves generate intersubjective meaning, computational tools make it increasingly possible to produce formal novelty and complexity. At the same time, architecture faces the demand for aesthetic experimentation that seeks forms adequate to a constantly changing global culture—one whose very dynamic is defined as a "tradition against itself." [121]

Indeed, structural designers today generally bypass spoken word and poetry, because they are considered imprecise and subjective, incapable of guiding the hand of the creator to translate conceptual design into real structure with precision. In our technological world, it is easy to imagine that the best language is one that speaks without ambiguity, where signs and meanings stem from precise mathematical equations, in a direct and linear relationship to life's problems. The simple communication we use in everyday life does not have this characteristic, and people in a technological civilization are inclined to blame this condition for all the problems associated with misunderstandings or subjectivity.

Pérez-Gómez finds hope for the collaboration between these two worlds in the imagination of the designer. He states:

...a linguistic model of imagination over a visual one embraces the poetic role of imagining, its creative potential. Imagining is folded into the function of metaphor: the ability to say one thing in terms of another, or several things at the same time, creating something new. This creative copula is always complemented by "seeing-as", which "contains a ground, a foundation ... resemblance." Thanks to the character of "seeing-as" as "half thought and half experience", it joins the light of sense with the fullness of the image. In this way the non-verbal and the verbal are firmly united at the core of the image-ing function of language. (Pérez-Gómez, 2016) [58]

Regarding the importance of both, Octavio Paz remarks: "Technique and creation, tool and poem are different realities. The technique is repetition that improves or deteriorates; it is heritage and change: the gun replaces the bow." [122] The shell of Louvre Abu Dhabi does not replicate the Baroque style of Louvre in Paris. He remarks that each poem is a one-of-a-kind creation, brought into being by a technique that disappears at the very moment of creation. [122]

A structure that is allowed to speak can reveal its aesthetic intentions, along with the values made possible by a productive poetic imagination, which have their source in human ethics and culture. The project of the building as a poetic hypothesis, in the words of Pérez-Gómez "is the suggestion or proposal, in imaginative, fictive mode, of a world." [58]

In contrast, the formalization of the ordinary, which is a condition for the process of generative design, means suspending reference to the ordinary. Structures, like architecture, like poetry, propose new possibilities of existence. Yet, structure in particular proposes possibilities that are more likely to be ours in the future, thanks to their high durability. Consequently, the effect of these structures in time is to orient people, through their actions, towards new realities.

Structural designers have been overwhelmed with promises from digital design in recent decades about some drastic changes. These promises come from recent developments such as 3D visualization of the design on the screen, coordination of design decisions through BIM programs, recent trends in computational design where data and parameters can be transformed into structural forms, and from the production of endless images by AI to suggest the initial idea. But this is a delusion. To examine the digital project, as we did with the modern project in Chapter 3, we must be careful not to detach it from time. That said, if I look at the computer-human relationship in continuity, such software were already present at the beginning of the 19th century, in Jean-Nicolas-Louis Durand's *Mechanism of architectural composition*.

Pérez-Gómez explains how developments at that time enabled design to undergo a “scientific reduction” that later facilitated the formalization of this process on computer screens. [58] Pérez-Gómez also explains that the promise of the digital project to model the full reality within itself is the same approach that Durand had when he sought to abstract reality and claimed that his mechanical compositions represented it. Indeed, one of the things Revit claims to offer is “to define forms and geometry as real building components for a smoother transition to design development and documentation.” [58] As a result, the structural design is abstracted into an image of the real structure that structural designers can easily play with and manage, but which, contrary to the promises of the software, in no way represents the full reality. Since software can also optimize construction processes, the dream (or nightmare) of seamless fabrication, which has been an expectation and an unquestioned absolute value of the technological world since the beginning of modernism, seems to become a reality. At this rate, design is again claiming to produce structures and buildings like machines, starting the process initially with beautiful-looking forms, with powerful marketing, and with images that are reproducible, which means that the structures in the images can be fabricated and turned into objects.

Deleuze is one of those who criticized the image of thought for its tendency to impose fixed categories and identities on reality, obscuring the inherent complexity of existence. He suggests that the image of thought is rooted in representational thinking, where concepts are seen as mere reflections or representations of pre-existing objects or ideas. To challenge the image of thought, Deleuze proposes a different approach; one that embraces difference and variety. He advocates for a mode of thinking that breaks away from fixed identities and

categories, and allows for the emergence of new connections and possibilities. [80] Indeed, the strategy of image fabrication hinders the referential potential of structures as a necessarily emotional, kinesthetic, and multisensory form of communication, an atmosphere that responds to the natural world and specific cultural values; all issues that are irreducible to binary information. Computer design programs, which promise to contain every aspect of design within themselves, said with concern in the words of Pérez-Gómez, “[have] unquestionably played a part in the continuing impoverishment of the built environment in our exploding universal megalopolis.” [58] This automatic process is an imperative instrumental that devalues the crafts that were previously involved in translating drawings and models into real structures. The simplicity that software can offer to manipulate forms, has led to blindness towards the experiential meaning of materials. Meanwhile, computer programs dedicated to a certain aspect of design—such as FEA software—have brought about extreme standardization and formal reproduction of structures, making it possible to build identical structures with homogeneous components, which do not respond to their location either in cultural or physical terms and have no connection to the context in which they are built.

Unfortunately, these aspects are mostly disregarded as unimportant in structural design software. The purpose of experiential interaction is to reflect situations and events taking into account their familiarity with people. Other arts such as painting can be kept away from society, locked in exhibitions, but buildings are destined to be embraced by society and are constantly in touch with the vicissitudes of life. In order to address the fullness of spaces, which are filled with everyday life and influenced by culture, structural design must allow room for change and ambiguity.

One of the challenges of design, according to Smail, is that “we grow increasingly numb to the mechanisms that stimulate our moods and feelings every day.” [123] Indeed, we get bored of what was offered a decade ago, creating a neurochemical desensitization in our brains to those solutions. Which means that for a mentality guided by pure human pleasures, architecture would function better as a drug that gives people maximum comfort and a little entertainment to avoid boredom. In this way, modern and digital design continues to promote itself by detaching us from past times and values and, consequently, making us forget about death while science tries to eliminate it altogether.

Until that time comes, (it will most likely never come) we are stuck inside our bodies. We are not just our brains and our brains are not just AI. Our consciousness is embodied in our bodies, and according to Dreyfus, it is in the connection between man and the environment. [107] We have feelings that guide us and the surrounding environment influences these feelings. Gilbert Ryle supports this idea when he denies the existence of a mental capacity within the brain organ. According to him, “there is nothing to see inside a human skull.” [124] Pérez-Gómez also states that “Introspection is only retrospection (about past

experiences—whether recent or long term).” [58] The same opinion is shared by George Lakoff and Mark Johnson, who, following in the footsteps of Merleau-Ponty and David Abram, state that the embodied mind is influenced by and is part of the life that the body makes and not the body as an object itself. [125] This means that the environment and the structures that we make are part of our consciousness. They are not simply collections of objects, but are indeed part of our being. In order to feel part of our environment, it is important to offer an ethical and empathetic design, which means that we must carry the same design values that we believe we should have as a society, as well as create structures in the service of man and society.

Another reason why we should take this step as designers is that the actual structural design does not carry a memory of real things. This makes us focus on memorizing concepts, and makes us treat all structures the same and judge them on the same predispositions. This brings about reproduction, rather than repetition—in the sense of the term that Deleuze uses. In reality, structures are not reproducible, but the lack of memory for real things makes us treat all transformed objects the same.

Humans do not seem to follow strict rules. Rather, they seem to use global perceptual organizations, making pragmatic distinctions between essential and inessential operations, adapting to different paradigms, and using a general sense of situations to derive meaning from them that they can apply to similar cases. Of course, all this sense of organization without establishing strict rules could still come about because of a set of rules that we follow unconsciously. However, when one tries to reason it out this way—by proposing that all human behavior comes from a set of instructions—one finds a regress to rules for applying rules. This regress cannot end with an appeal to concrete facts since, if we are to proceed from the initial proposition, all facts themselves must be known and interpreted by rules. Consequently, this proposition does not hold merit.

Computers can only work with discrete facts, but man, who is the source of facts, is neither a fact, nor a set of facts. On the contrary, we are the ones who create these sets of facts during our encounters with the world. This world is perceived by us involving our sensory capacity. There is no reason to suppose that the same reality that we perceive can be perceived differently by any other means.

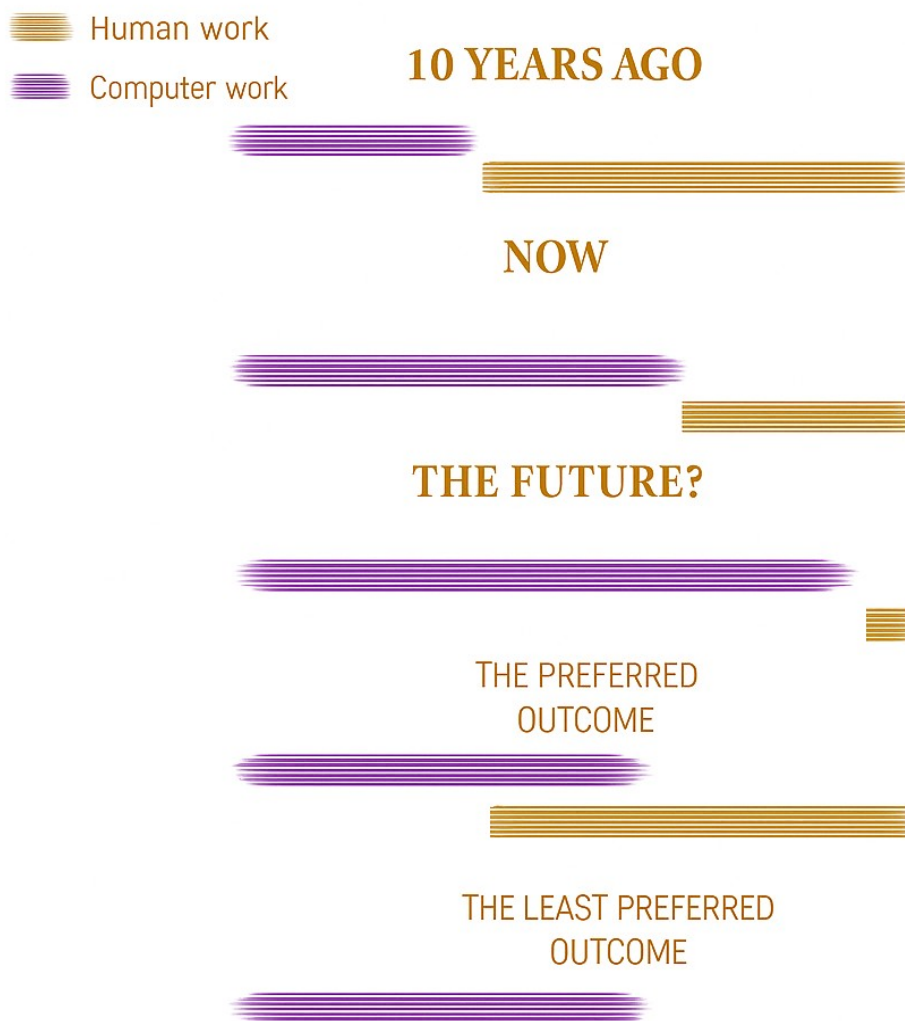


Figure 62 - Human-computer interaction in work across different zeitgeists

"Man and computer are capable of accomplishing things that neither of them can do alone."
(Rosenblith, 1962) [126]

It is therefore important that structural design process can be divided into four categories inspired by the four types of intelligent activities, distinguished by Dreyfus. [107]

Zone I is where simulation activities feel embedded in reality. This zone includes all forms of elementary "associationistic" behavior when meaning and context are irrelevant to the activity being undertaken. Simplifying the equations of mechanics by creating one system of equations for linear equations and using numerical methods to solve non-linear equations, for example, is one of these activities.

Zone II is the domain of geometry, which is the most preferred region for the computer. This zone represents conceptual reality, rather than full reality. Problems here are fully formalized and fully computable. For this reason, it may be referred to as the formal zone. In this zone, the application of artificial intelligence or generative mechanical methods may be possible, and evidence has shown that almost any problem within this zone can be solved by the computer, except for those that go beyond the computing capacity of the time. The later problems may involve very complex structures or searches for optimal solutions in an extremely large and highly nonlinear space of possible solutions—such as dams. Nevertheless, it is likely that a time will come when all formal problems in this zone will be solvable. In zone II, simple natural communication is replaced by formal language, which is guided by logic. This zone includes, for example, games that have precise rules and can be completely calculated, as in the case of chess or Go, and geometrical model analysis. Pattern recognition at this level is done through direct identification, which is performed by defining a list of traits that characterize the elements that belong to this class. Problem solving is concerned only with reducing the distance between inputs and outputs, which is an aspect of optimizing optimization. Formal systems in this zone are simple enough to be manipulated by algorithms. Heuristics—those that really involve searching and using human intuition—are not necessary in this case. Whereas computer heuristics may be necessary if problems are non-linear.

Zone III includes all problems that require real heuristics—human ones—, which is, for example, structural analysis. In this case, it is only in the hands of the structural designer, not the computer, to understand and decide with what elements the structural system will be modeled. The reason for this is that the analyzed model must give reliable results and at the same time be as simple as possible to facilitate the process of calculations by the computer, as well as to save time and avoid losing insight.

Zone IV can be called the zone of informal behavior. It includes all those daily activities in our reality that are regular, but not regulated by clear fixed rules. The most obvious example in the case of structural design is the conceptual design. This area also includes conversations with colleagues, clients, users of structures or any other form of participation, including the communication between the designer and the environment. Pattern recognition in this domain is based on recognizing the general and the typical using our human skills. Problems in this area are open-ended, which means that they require a definition of what is relevant to that situation and require that in order to solve them you must first enter that situation. The techniques followed in these cases either are learned from previous examples and experience, or are followed by being guided by intuition without applying any predetermined rule (in most cases it is both). In this area it is necessary to have a sense of general rules since it is impossible to start with an infinite set of facts since the situations are infinite. However, you must be prepared that the plan will most likely change along the way and always call into question the rules predetermined at the beginning. This area is not touched by the computer. It is an area where only human intelligence and commonsense can seek to provide solutions.

Since zones I and II can very well pass as computer jurisdiction while zone IV is the property of humans, the zone where the human-computer relationship must be functional and symbiotic is zone III. For this relationship to work, several conditions must be met:

1. Since the computers we use have neither bodies nor senses, in the terms that we described in this chapter, and since no one has any idea how to program the global organization and indeterminacy that characterize our embodied, perceptive sensory motor skills, the best we can hope for is a kind of first-person designing, which allows the structural designer to experience a part of reality firsthand. Of course, it is difficult to propose and demand more from the computer other than this. What is being asked in this case is to deal with the field of experience before it is decomposed and abstracted into predefined objects, but a pre-objective experience is by default outside the framework of a computer.
2. A second difficulty is shown in the connection between the representations of the problem in a problem-solving system. In this case, the recognition between essential and non-essential must be put into practice. For example, when modeling structures to perform structural analysis, the designer must reason about which elements of the program can best represent the loaded state and the stresses of the structure. Mitchell Feigenbaum supports this statement by saying: "Choosing a representation that is right for a problem can spectacularly improve the efficiency of the solution-finding process. The choice of problem representation is the job of the human programmer and is a creative act." [127] Therefore optimizing optimization is more important than the implementation of the optimization method itself.

3. Since computers are not in a situation, and since no one knows how to program primitive robots to situate themselves in the world we live in, structural designers are faced with the problem of how to program the external environment into a computer. As already mentioned, programming every situation and every solution for that situation is impossible because, even if the world were a set of millions of facts, computers would not have sufficient capacity to store all of these facts. Not only that, but increasing the possibilities would complicate the process because no one would know which situation would correspond to a given solution. The reason this problem does not affect humans is that our model actually is the world itself and we are already situated in it.

Of all these four zones, the one that is expected to have the most progress in the future, with the advancement of computers, is zone II. Whereas the zone III requires symbiotic collaboration between men and machine. In the words of Dreyfus, this means: “we must couple their [computers] capacity for fast and accurate calculation with the short-cut processing made possible by fringe-consciousness, insight, and ambiguity tolerance.” [107] Which means that there is no method that enables us to automatically discover the most adequate structure. The idea of “the more control the better” is put into question here. The computational design process must make room for contingency. At its core must be the implementation of strategies for negotiating between interest groups and then providing creative solutions.

Another aspect that must be taken into account is visual thinking, in the sense of its relationship with visual perception in simulation and cognition. Birger Sevaldson explains that visual thinking plays a crucial role in the generative design process, where the outcomes of generative work are examined, coded, and re-coded. [128] This practice of visually analyzing and restructuring material is essential for unlocking the generative potential of graphic computing. He adds that visual computing strengthens and expands the visual dimension of design, supporting exploratory and intuitive approaches such as form-making, composition, play and game-based methods, diagramming, and the mapping and evolution of complex processes. [128]

Another important characteristic, which has been mentioned several times so far, is the ability to negotiate design values. Sevaldson in fact states that in addition to negotiations with those interested and affected by the structures, negotiation is also an important aspect between the computer and the designer. [128] And indeed, despite the strict rules that we established above for the division of zones, the possibility of making transitions and delegating tasks to the computer and vice versa, although not recommended, in certain cases is potentially possible. No one can deny a structural designer the pleasure of solving structures by hand, for example. Also, when time is of the essence, no one can blame a designer for having handed over all the design phases to the computer as long as at least some primary objectives/conditions are achieved by optimization methods—such as

functional and mechanical aspects. The ability to negotiate means accepting contingency and accepting that the effect of the situation constitutes a precedent in design, capable of questioning all predetermined values. Problems of control and negotiation lead to an imperfect and variable approach to design rather than seeking to achieve a perfect and complete composition. This allows a design solution to have a greater potential to adapt to future changes. It allows the implementation of the concept of unfinishedness and open-endedness. Another unconditional value is that of interdisciplinarity. I said in chapter 3 that structural design is a field heavily influenced by social and cultural aspects, and structures collide with people in everyday life. They are the ones who judge the value of structures. This means that structural design should enable joint decision-making by all groups affected by the structure from the earliest stages of design. Finally, since the computer and the designer both carry certain values, it would be good to involve both parties during a structural design.

According to a study, at the Technische Hochschule Würzburg-Schweinfurt (THWS) in Germany, ChatGPT and other LLMs recommend significantly lower salaries to women than to men. As the study points out that bias persists even under identical conditions: Same background. Same role. Just a different pronoun. And suddenly, women are told to ask for 20% less. [129] Models trained on historical data inevitably reproduce past prejudices unless deliberate changes are made.

Noam Chomsky is among the few scientists who warn of this risk. He argues that the lesson is not to discard valuable tools, but to keep enough perspective to recognize when the research they enable ceases to be significant. At the same time, he stresses the importance of appreciating ideas and insights that may be premature, imprecise, or not yet researchable, but remain relevant to the advancement of knowledge. [130]

Taking these warnings into consideration, I will explore three characteristics of humans, which are neglected by computers, but are extremely important for structural design:

1. The role of the body in organizing and understanding objects;
2. The situational factor, which provides unique possibilities that do not resent a certain manual of instructions;
3. The human needs factor, which classifies objects as relevant or not.

The Phenomenological Factor:

Even Simon, who is one of those who believes that AI will achieve human intelligence, admits that AI will have a very difficult time covering the field of perception of the senses and the body. He says: “Automation of a flexible central nervous system will be feasible long before automation of a comparatively flexible sensory, manipulative, or locomotive system.” [131] However, from what we have seen so far, the central nervous system, which Simon takes for granted that AI will fully adopt it, is in fact dependent on the locomotive system. In other words, what we think depends on what we experience. We perceive a building, for example, as more than just its facade, as if it had a horizon, a kind of depth. We firstly encounter its image, and then absorb its other characteristics through the inner horizon. A computer without an equivalent tool that perceives the inner horizon of buildings would do this process in reverse: it would first create an image of the details, then of the whole. In Rhino or Revit, for example, we might isolate and examine a beam or joint, but its meaning in the structure is only accessible if we call up the surrounding context. In contrast, even when we walk into a half-finished building or look at a structural drawing, we do not need to see every member to experience the system. Instead we carry forward a bodily and cognitive horizon shaped by training, prior designs, and spatial sense. We anticipate the existence of supports, loads, continuities, not as precise data, but as meaningful presence. Of course, we may still need analysis to confirm the structural behavior, but we do not start from scratch. A computer does.

For an AI developer, it is enough to assume that intelligent behavior can be produced from passively received data and then, by processing it in a computer, one can describe the full characteristics of the structures. However, as we have already seen, being embodied in the world creates other possibilities that the computer does not have. The senses and the body give us the inner horizon, which is partial data, not fully defined yet, about the world around us. They also give us the global sense of perception, which allows us to see the Whole without having to start from the details. Finally, they allow us to transfer these perceptions in-and-out across different senses and of course in our mind, as well as have a dynamic perception depending on the situation. For example, when our body feels the shaking of the earthquake, our heartbeat increases in fear and suddenly our senses become more alert. All these benefits come from our sensory motor skills. Thanks to them, we can dwell in our world with ease without having to formalize everything.

The Situational Factor:

We saw how human behavior could be regulated without the need for formal predetermined rules. This is not a luxury, but a basic need for living. The reason is that, because there are an infinite number of possibilities for different situations, it is also impossible to regulate everything because no one can create any predetermined rules for every situation. Open-ended problems, unlike problems that have a solution manual, present additional difficulties. To solve them, structural designers must first determine which values are relevant to that case, and then determine which of those relevant values are essential and which are non-essential. There are even values that are discarded before ever entering the situation, because our culture no longer accepts them as relevant. Since values are either situationally irrelevant or relevant, depending on the person's goals, all values are potentially possible in any given case. Therefore, the situational factor operates in both cases; in certain cases, there is an infinity of values that are relevant, while in other cases there may be an infinity of values that are not relevant. Since the computer is not situational, it must treat values as possible all the time. This puts AI researchers in a dilemma: either they must store an infinity of values and information for them, or they must artificially remove some of them. Even Minsky concedes that no one truly knows how to store the vast amount of information required for thinking in a computer. [118] He explains that problem-solving involves handling numerous statements, definitions, associations, and a network of goals. This means managing not only facts about objects and their relations but also higher-level facts about facts, classes of facts, and their interrelations. While heuristic programs can demonstrate principles effectively on small models, they become inefficient at larger scales. Issues such as looping, branching, tracking progress, and monitoring processes then consume a disproportionate share of computational effort. [118]

Whatever kind of things that enable us humans not to consider a part of values without having to eliminate them forever is a mystery. However, for Dreyfus the answer is simple: "It has to do with the way man is at home in his world, has it comfortably wrapped around him, so to speak." [107] He explains that humans are always already situated so that what they require to engage with things is arranged around them, not stored away like items in a trunk or neatly catalogued in a filing cabinet. "This system of relations which makes it possible to discover objects when they are needed is our home or our world." [107]

To put it differently in less metaphorical words, Charles Taylor explains:

Much of a human being's knowledge of situations and their possibilities is know-how, that is, it cannot be exhaustively unpacked into a set of specific instructions or factual statements, but is a general capacity to generate appropriate actions and therefore, if necessary, the "instructions" underlying them. Usually we think of this kind of indefinitely unpackable form of knowledge as bound up with the know-how which underlies our actions. But the same kind of knowledge underlies what we suffer, our "passions". Thus just as I have a general grasp on what it is to walk around, use my hands, drive a car, conduct a case in court (if I'm a lawyer), etc. so I have a general grasp on what it is to be threatened, to hear good news, to be jilted by my girlfriend, to be made a fool of in public.

How does the handicapper recognize just those odd factors which are relevant? The answer is that if we understand our grasp of the world as arising out of our dealing with it according to our different capacities, and our being touched by it according to our different concerns, then we can see that the problem of how a given concern or purpose comes to select the relevant features of our surroundings doesn't arise. For being concerned in a certain way or having a certain purpose is not something separate from our awareness of our situation; it just is being aware of this situation in a certain light, being aware of a situation with a certain structure. Thus being anxious for my own life because I have fallen among thugs is to sense the menace in that bulge in his pocket, to feel my vulnerability to his fist which might at any moment be swung at my face, and so on. (Taylor, 1992) [107]

The whole of reality is modeled according to human intentions in the sense that what is perceived as structure or what is important about a structure is already a function of that modeling—the modeling we do of reality. This is something that computers cannot offer because they can only deal with finite, context-independent, discrete structures. Computers can go so far as to question facts about structures by presenting facts for facts that can be governed by design values, but the computer ultimately always needs discrete values to guide the whole process.

Meanwhile, as mentioned earlier, we are also situated in time, which means that our values and our prior knowledge give us a clue as to what we can ignore in the future, as well as what might be relevant or essential. Which means that the hierarchy of values and the discrimination of some of them is essential to the way a computer organizes facts and values. However, in full reality, all “facts” and “values” are equally important because they are there, they exist. We simply have access only as much as our body’s potential allows us—say, for example, we are unable to navigate the world of atoms or electromagnetic waves. In the words of Ulric Neisser: “There is certainly a real world of trees and people and cars and even

books..... However, we have no direct, immediate access to the world, nor to any of its properties.” [132]

While we are at home in our world, the values of structures, which we perceive through direct contact with the world, are not codes stored in our minds that are expected to find the situation—the input—to give meaning—the output. They are in fact the world itself. The Input-Output idea makes no sense in this case. There is no reason to suppose that the whole of reality can be analyzed into discrete elements, and even if such a thing were possible, no one would know how to perceive certain situations in reality with certain codes in a computer. To deny this theory is not to deny that the physical energy of the world bombards our physical organism and the result is our lived experience. It simply means that the way we create perceptions is not done according to codes and we do not have a storage of millions of facts about different situations—say, for example, about when to build a Warren truss or a Pratt truss.

As for how structural design should be regulated without imposing strict input-output rules, the best way is to use true⁴ heuristic methods. Both Wittgenstein and Heidegger endorse this perspective, illustrating genuine heuristics with the example of traffic lights. [133] Traffic regulations, they explain, allow or prohibit certain actions for drivers and pedestrians but do not attempt to prescribe every aspect of their movement. Moreover, it would be meaningless to speak of an “ideal” traffic order that controls everything, since such an ideal cannot even be imagined. Making regulations stricter in some respect does not imply moving closer to such an unattainable ideal. [133]

This way of establishing rules without creating real algorithms has in fact also been followed by computer methods, specifically the ones called optimization methods. We will discuss them in the next chapter, but as I already mentioned, they are not true heuristics. Consequently, although they allow us to solve many problems in structural design, they do not negate the importance of the designer's intuition in solving problems using true heuristic methods, which are guided by human insight and pattern recognition.

⁴ I use the word “true” here because digital design has already taken up the concept of heuristics and mistakenly uses it as an equivalent of non-linear solvers.

The Human Needs Factor

"How are you going to find that thing whose nature is completely unknown to you? The answer is to lose your way." (Solnit, 2006) [134]

We are at home in our world and can find our way in it because it is our world produced by us, which we perceive as the context of our basic needs. What does this mean for structural designers? If our world is modeled according to our needs, then why is computer modeling, which is also coded according to our needs, insufficient to grasp the full reality? We have seen, however, how explicit objectives do not work even for organizing simple design problems. These difficulties of objective-outcome analysis suggest that for a computer to solve design problems, it is not enough for the device to have an objective and measure the output fitness⁵. Design requires that we first determine the values of our project, which must then be translated into objectives, before we build scripts to measure the possibilities of solutions that approach these objectives.

The difference between social values and the objectives that computers can manage was noted by Satoshi Watanabe, who explains that "for man, an evaluation is made according to a system of values which is nonspecific and quasi-emotive, while an evaluation for a robot could only be made according to a table or a specific criterion. This difference is subtle but profound." [135] He argues that humans possess values, whereas machines only have objectives. Although people also pursue objectives, these are shaped by underlying value systems and do not dictate action in the absolute way they do for robots. Once an objective is set, a machine can follow it just as a human can, and utilitarian behavior can be simulated if probabilities and utilities are pre-defined. However, what a machine can never access is the very source from which human utility and value originate. [135]

Watanabe also mentions that these values are essential for intelligent behavior. [135] According to him, there are an infinite number of hypotheses that are supported by human experience, but not all of them are taken into account. The limitation of these possibilities is made by a system of values that designers have for the structures they are working on. But why by a system of values and not by a list of objectives? How do these two differ? So far the only difference seems to be that the values are more vague. But this does not prevent programmers from making computer objectives more vague and weighing their values based on statistical approaches. However, Dreyfus points out another difference between them, which according to him, can only be understood if "one must first abandon his way of posing the problem." [107] He continues his argument that, in order to understand this difference, "we must be able to distinguish between objects, and the field or situation, which makes our experience of objects possible." [107] Which means that what Watanabe mistakenly considers as values are in fact characteristics obtained from human perception, not

⁵ A word derived from evolutionary theory: survival of the fittest.

necessarily the real value of the object or reality. Based on Heidegger's analysis of this aspect, since designers do not know the objectives of structural projects from the beginning, they do not know them even during the design, until they finally complete the project. [86] For him, there can be no list of predetermined objectives that an open-ended creative project must fulfill. This does not mean that structural designers should not have design values during their work. In the words of Dreyfus, “our needs are determinate enough to give things specific meaning for us, and many of our goals are quite explicit.” [107] When we experience a need, we do not know that it is such without first experiencing it. Which means that we have to search ourselves to discover them. This is not done simply by exploring different forms of structures with different objectives and conditions, but again through experience, through a sense of gratification. This emotion is experienced when we discover what we have wanted all along, but it also comes with a bittersweet feeling that we were not able to accurately predict its value upon discovering it

Structural design does not come with a generic table of values that we must follow in our work. Nor is this agenda filled with professional experience and then the values you have learned along the way can be freely applied to future projects. Instead, only by discovering the values of design during the design process, which is a process that does not stop until the end of the project (actually even after the project is finished through the aura of the structure there is room for reflection), the designer finds his way to them.

The example I am going to give you about this argument has probably crossed your mind by now (if not, I feel sorry for you). When a guy falls in love with a girl, he discovers that the characteristics of that girl were what he wanted all along, but he couldn't understand this at all before falling in love in the first place. That is to say, after he experiences the emotion of love, the values that represent a girl are created based on the characteristics of the girl he loves. Gradually he becomes a man, who needs that specific relationship, and his mind sees these characteristics as values that he has always wanted, even before he knew the girl he loved. This back-and-forth change of the narrative regarding values makes possible a new order of meaning in the world that is neither predetermined nor arbitrarily chosen.

The only portal to the quantum world is through our emotions. They are charged with infinite potentiality and free will. Through emotions you can influence the states of your quantum field which precedes and cascades to the physical life. To explain it in the context of construction, as long as certain conditions are met, we feel like we are at home, regardless of whether that building was built by an architect, or a non-professional. No one can deny the benefits that architectural and structural designs have brought in the construction field. However, the purpose of design in general goes beyond the material or environmental qualities or the functions that a house should have. In the history of life, regardless of their possibilities (or precisely because of them) we have witnessed how people fill rented structures, or tents or caves, with dreams and memories and call them their homes.



Figure 63 - Göreme, Cappadocia, Turkey (author, 2022)

If the primary role of structural design is to serve man, then the highest potential a structure can have is to provide a home. It is structure, a place of self-realization and spiritual fulfillment, comparable to the erotic experience, instead of just structure as a law-governed shell that suffices to stand on its feet under the action of loads. Structural design, although often misunderstood as a technical procedure because of the vast technical requirements to achieve the product, is in fact part of architecture—in the sense of architecture as an activity for man. When structures are best realized, they offer the possibility of psychosomatic completeness, of whole-body health, and of social well-being. It is therefore regrettable that avant-garde practices are seeking to generate structures through top-down processes using computer power and prefabrication techniques, without involving the human hand in these processes. The lack of human touch makes these projects disconnected from the meaning of places, from the poetry of materials and from cultural values.

However, human touch is subjective and by this term, the modern and digital project imply “weakness”. The modern project stood its ground especially with the criticism of the aesthetic values of buildings. In fact, even the post-modern project does not seem to embrace aesthetic values because they are in contrast with the idea of fully embodied sensory experiences and increase the hegemony of the eye. However, what if aesthetic values have never been related to beauty or taste? Pérez-Gómez suggests another approach to aesthetic values, more acceptable in the world we live in. He states:

Leaving aside all arguments among dogmatic religions, discredited by their claims to an absolute and exclusive truth, and acknowledging the disenchantment of the human environment brought about by a rational proclamation of the death of God, there are numerous occasions when all of us, regardless of what we believe, feel beyond doubt that life is worth living. This is the core of aesthetic experience when properly understood, the capacity of “that which appears” to reveal a sense of purposefulness—be it the smiling face of a child, a poem about love by Sharon Olds, a calm sea, a glorious sunset behind the mountains, or an “unfinished” slave by Michelangelo. (Pérez-Gómez, 2016) [58]

Far from being a characteristic of beauty or ugliness, aesthetic values, in the words of Hans-Georg Gadamer, are “simply what appear”. [136] They can appear as man-made artifacts of another era or as structural solutions achieved by technological novelties. Aesthetics, therefore, in this case becomes the message that the structure conveys through its aura, encouraging us to ignite an attunement approach with the surrounding environment. It is precisely this sense of attunement that, according to Pérez-Gómez, is being eroded by the production of phony structures. [58] People are becoming less and less interested in the simple life, and neither architecture in general, nor structural design in particular, are helping to stop this. What construction needs is to advocate for the small moments, which for man have so much importance, not for the display of technological power and big screens. Pérez-Gómez notes that most of us remain unsettled by the almost indistinguishable “qualities” of car parks and housing blocks, or of airports and corporate hotels, which seem designed only for transit rather than lingering. He wryly adds that one can, of course, burn a little incense and light candles to create a romantic mood in a room—so long as the smoke detector stays quiet and the motion sensor doesn’t switch the lights back on at the wrong moment. [58]

The image of a floating structure that defies the laws of gravity, for example, may offer a sense of adrenaline and wonder, but beyond that, does not have much social value. It is not cognitive, in the sense that it is not capable of representing lived life. As a result, it is not capable of interacting with people during their lives in the same way that one of the stone structures in Göreme, in Cappadocia, interacted with its inhabitants in the 6th century (fig.63).

5. OPTIMIZATION AS DESIGN TOOL AND MEDIATOR

Chapter 5

5.1 Optimization as Mediator: Dealing with Simulations

“We actually made a map of the country, on the scale of a mile to the mile!”

“Have you used it much?”, I enquired.

“It has never been spread out, yet”, said Mein Herr. ‘The farmers objected: they said it would cover the whole country, and shut out the sunlight! So we now use the country itself, as its own map, and I assure you it does nearly as well.’ (Carroll, 1876) [137]

Be creative

The first step in computer-aided design is the project idea. As the name suggests, the initial idea is very important at this stage. John Hegarty says that the biggest misconception about creative ideas is that they are confused with originality. [138] In fact, nothing can be completely original. New ideas actually come from inspirations from the world around us that are interpreted in ways that we have not seen before. In addition, a problem is never so original that it does not have a similar precedent, but this does not mean that we should limit our imagination, especially in the first concepts. The creative process consists of four steps. Hermann von Helmholtz formulated the first steps in the 19th century, with a fourth step added by Henri Poincaré in the early 20th century. [6] These steps are saturation, incubation, illumination and verification. Saturation means that you have to immerse yourself in the field of structural design, solving as many building problems as possible in different ways. If designers only know one way of doing things, they will have a hard time adapting to previous cases. You also have to study a lot, get as much information about the construction as possible. In fact, the truth is that at this stage any information about everything is valuable; the more you know about anything, the better. Incubation comes from thinking about the problem, deciphering it, and doing research about it. This stage takes time. Illumination is the stage when a “spark” suddenly comes to your brain. Personally, I have had some ideas for writing scripts in Grasshopper in my sleep; I would go to bed tired because I could not solve a problem and the solution would come to me in my dreams. This does not mean sitting around waiting for ideas to come to you. There is a reason why the previous stages exist. For example, Murray Gell-Mann did indeed win the Nobel Prize for a mistake he made while teaching, but it was his background knowledge that gave him the opportunity to verify this situation and realize that it was not really a mistake, but was actually a finding. Finally, the verification stage is the process where structural designers seek validation, that is, they seek to have the findings checked. It is important that, in addition to simulation validation and checks within the design expertise, you also have validation from the everyday world.

Objectives and constraints

According to Debney, creativity in structural design does not grow when you have a blank page and no constraints but, on the contrary, when there are demands, limitations and possibilities. [6] A demand could be a client coming to you and asking for a structure for a villa or an architect asking you to build a villa together. As for constraints, they are important, but they should be put aside at the beginning. At the beginning, it is good to start with, what might be possible. This opens your mind to different options. From these possibilities, you can slowly filter them depending on the limitations. In other words, information stimulates imagination and creativity. The worst thing you can do to have ideas is to start from your own impossibilities. That said, Debney suggests that constraints, such as load-bearing capacity, for example, should be taken into account at a later stage, not at the conceptual stage. [6] They become important later, during the detailing phase. Another important aspect of creativity during design is that the designer should be willing to offer several solutions, not just one. We should also keep in mind that one of the best ways to solve a problem is to eliminate it altogether. For example, if a structure has difficulty being built on a site, then an idea might be to choose another site to build it on (of course, if the possibilities are there to do so). The possibilities for doing this are rare, but with the same logic, we can find ways to eliminate excessive loads, to remove snow loads from roofs, to reduce wind or earthquake loads, to refuse building an unethical structure etc. There are several cases worth mentioning of the way a designer works on a project idea on the computer. One of them is suggested by Eisenman, whose methodologies are based on diagrams and abstractions that can be adapted very well to computers. [139] As for diagrams, Stan Allen mentions that they can revitalize the design process. According to him, diagrams are not schemes, formal types or paradigms, or other regulatory tools, but are placeholders. [128] That is, they are simply instructions for actions or contingent descriptions of possible formal configurations. They work as abstraction machines and do not resemble the structures they produce. Such methodologies are welcome for the conceptual design as long as there is an interaction between diagrams and the designer's interpretation. I have already explained that methodologies that leave no room for interpretation are not good for this phase. Structural optimization, or even environmental optimization (if this term even makes sense), for example, does not necessarily make good structures, precisely because it bypasses the design idea of the structure. For example, building a giant geodesic dome covering an entire city could be structurally possible since triangular fractals and spherical shapes make it possible to distribute loads without straining too much. In addition, this structure can improve some energy performance aspects by reducing air pollution, cutting heating and cooling costs etc. However, this has never been done, not because it has never occurred to anyone (on the contrary, Fuller proposed it in the 1960s to cover Manhattan), but because such a project has very little real value (fig.64).



Figure 64 - The 1960 plan to place a dome over Midtown Manhattan, adapted from Carlson, 2012 [140]

Indeed, the cost of construction and maintenance would be very high and the social interactions with it would be very low. After all, not a single person would interact with it except for the fact that the citizens would have to see it above them all the time and be trapped inside the cage. Once a professor of mine addressed this issue with an ironic tone when he explained how Buckminster Fuller did everything right and solved everything with his geodesic dome, except that he forgot to put a door somewhere.

The fact that computational objectives in structural design provide completely different solutions and forms from each other shows once again the importance of the pre-design phase, which must be dealt with by the human touch. For example, lightweight design are different from cheaper design, different from time-efficient design, different from easily-built design.

“Engineering problems are under-defined, there are many solutions, good, bad and indifferent. The art is to arrive at a good solution. This is a creative activity, involving imagination, intuition and deliberate choice” (attributed to Ove Arup, mid-20th century) [6]

Even the structure of a house, which at first glance seems like a simple structural project because the construction constraints are very easily met, becomes a complicated case when we consider its design objectives. The opposite is true, for example, when we consider the design of a spaceship that will go to the Moon. Although the constraints involved in this case are extremely difficult to meet, the objective is simple and clear. This contrast between objectives and constraints is significant in design.

You will not solve everything, and that is okay

Paul Rudolph, drawing on a remark by Mies van der Rohe, reminds us that design cannot be reduced solely to problem-solving. “He [Mies] says: ‘All problems can never be solved.’ ...Indeed it is a characteristic of the twentieth century that architects are highly selective in determining which problems they want to solve.” [53] Rudolph explains that Mies creates remarkable buildings precisely because he chooses to ignore many aspects of design—if he attempted to resolve them all, the strength of his architecture would be diminished. [53] With this example, I want to show that you can actually define an infinite number of objectives to be achieved and put them to the computer and, if the processing power were not limiting, it would give you a solution for your project. However, this solution does not necessarily make the project better. It is in the hands of the designer to select the objectives to set and then to separate which ones are essential and which ones are non-essential.

Two examples selected from the communist period in Albania will illustrate how optimization does not necessarily lead to the success of the structure. The first is the red brick Socialist housing complex in Albania from 1945-1990 (fig.65), which were designed with the constraints of having very little funding for their construction; the second are the communist bunkers in Albania around these years (fig.65), designed with the objective of withstand maximum dynamic loads provided that they offered temporary shelter.



Figure 65 - Red brick masonry buildings of the Comunism period, Albania (author, 2025). Bunkers of the Comunism period, Albania (photograph by Aulon Harizaj, 2023, used with permission)

In Albania of those years, structural designers often found themselves in the role of “objectifiers”, meaning that they could do more with less. The remedy prescribed was to construct buildings with as less funding as possible, as long as the conditions set by the designers were met (such as achieving certain spans and load-bearing capacity). The construction was done by “volunteers” (people were forced to work actually, but the politics treated it as community duties). In addition, during the project, it was decided to remove the plastering along with the thermal insulation to keep up with the reduced funding. In the case of bunkers, the conditions were reduced to the absolute minimum in terms of living space, a minimum referred to as “existential”. However, the strength requirements were not just a high-restricted value to be met. It was actually an objective; a need to achieve the most possible strength of a structure that met some minor constraints (like the spatial requirements I mentioned above). The bunker designers offer a series of brilliant solutions, suggesting variants that not only reduced square meters and cubic meters per person, but everything superfluous by making an abstract calculation of essential psychological behavior. By focusing on the problems of “How” to achieve the highest strength possible, they missed the opportunity to address the truly important cultural needs. Today, sixty years later, we see how the red brick buildings are still habitable, even though they are nearing the end of their expected lifespan, while the bunkers are relics of a time and promise that does not exist. Naturally, the question arises; why do structures necessarily have to be as resistant as possible? If the bunkers were made resistant because someone believed a war would start and it never started—it wasn’t even close—then what is the point of them achieving the objective of withstanding the loads, when they never had the possibility of withstanding them, except on paper? Apart from a few sporadic cases when the bunkers were used as museums or warehouses, the dominant part of them was never used, at all.

Even if the bunkers were used for the purpose for which they were built, is it really important that a structure can support as much load as possible? Strength is important, but if structural engineers got something right during their university, is that the load-bearing capacity should be “almost equal and a bit higher” than load combinations. By this logic, strength should never be an objective (as much strength as possible), but rather a constraint (enough strength).

However, even in the case of red brick houses, where the load-bearing capacity was a constraint and the construction cost an objective, we have the right to ask “why” we should build as cheaply as possible and not, for example, rather expensive. Why instead of trying to optimize the forms to achieve spatial conditions to minimize costs, when in fact we can make dwellings spacious, safe, insulated, comfortable, well-equipped, have privacy, communicate, interact, nurture creativity, etc.

Nobody can be satisfied with an answer that appeals to the scarcity of available resources when we know how much is spent on wars, missiles and anti-missile systems, on moon

projects, on research to defoliate forests inhabited by partisans or to paralyse demonstrators emerging from ghettos, on hidden persuasion, on inventing artificial needs, etc. (Giancarlo De Carlo, 1992) [89]

Working to know “How” without a rigorous control of “Why” inevitably removes reality from the design process. Refusal to take into account the contribution of others in controlling the forms of structures is a typical manifestation of the idiocracy of forced specialization that we have already discussed. The fact that structures are optimized towards one aspect—say the economic aspect—and designers work hard until they achieve that objective, can come at the expense of other aspects that have not been taken into account. In fact, in red brick buildings, the economic aspect came at the expense of thermal comfort, more air, more light, more water and humidity resistance, all of which were eliminated because they conflicted with the economic aspect. Which means that, not only was the problem badly defined, but its solution was destined to be flawed.

Not only that, but when the constraints of the optimization process are set, sometimes not meeting all the conditions leads to a much higher fitness of the objective you want to achieve. Consider the example of penicillin and the creation of antibiotics. What Alexander Fleming realized was that a mould that was actually harmful to humans was the key to defeating many other dangerous bacteria in the human body. Similarly, if one or more of the constraints become more “tolerable”, this may change everything about the achievement of the objectives. In the words of Canguilhem, “the normal and the pathological are, but for minor quantitative differences, identical.” [36], constraints and objectives only differ in the values that the designer wants to achieve. In essence, they are interchangeable. Not only that, but constraints, as well as objectives, are just mere abstractions that do not represent the full reality. They are useful, but misunderstanding them as boundaries that set apart bad design from good design can be a dangerous thing to do. Sometimes just by tolerating constraints a bit can lead to an amazing design.

Optimizing Optimization

An essential aspect of any computational analysis, that includes optimizations, is asking the right question. It may be true that with enough time and computing power, you can examine and compare all possible solutions and choose the best one, but ample time is almost impossible to find under normal design conditions.

On the other hand, before building programs that automate processes, ask yourself the question: "Will the time I will save by using this algorithm be less than the time it will take me to create it? Is it worth it?"

Optimization involves automatic exploration of the design space⁶, but we are the ones who define what the design space will be. No matter how sophisticated the optimization process is, it can only test the possibilities that we define. You cannot have an infinite number of parameters and expect the answer to be a finite number of values. True genetic algorithms, the evolution of life on Earth has produced some amazing and complex things, including us, but it took more time than most customers would find acceptable.

As structural designers, we are used to dealing with algorithms. However, before giving directions to the computer by implementing algorithms, we should be careful of not creating programs that never finish. That thing is easier than it looks. Such an algorithm can be:

As long as $x > 1$: $x = x + 1$

In the case of optimizations, you do not have the luxury of being certain. We may find an answer that is good but there is no guarantee that it is the best answer or that we would even recognize it as such if we found it. In this case, we usually use computer heuristics, which are strategies to achieve a good result within a certain time. The product of a computer heuristic is an algorithm.

Computer heuristics may seem like a bad option at first until you realize that there are many situations where algorithms fail us. As a general rule, you should always use algorithms as a first option when possible, because they are fast and precise. Deterministic algorithms are linear, so they work well with linear problems. Nonlinear problems are not solved with the first option, and this is where computer heuristics come into play. A general rule of thumb is this: a computer heuristic is a good method for nonlinear problems and an abstract but useful model is a good method for linear problems.

Any good optimization routine should be a balance between exploring the design space and using the results found so far. Exploration means searching. Monte Carlo is an extreme example of this as it just explores, choosing points in the design space at random. Using the results is the opposite: constantly improving the answer until you can no longer improve it.

⁶ The design space includes all the possible solutions for a certain problem.

Gradient Descent is the classic method of using the results, as it will go to the local extremum completely unconcerned with other options. Good optimization methods, therefore, get a little bit of both. Genetic Algorithms explore like Monte Carlo, but also use the best options by crossing them. With Particle Swarms, one individual uses the best option while others continue exploring across the design space. Simulated Annealing starts by exploring, but then gradually changes its approach using the results as the optimization continues.

In a problem, when you are optimizing just one parameter, such as weight or shape for a given load, it is normally easier to tell when you have found a good solution. However, it is much more difficult when you are trying to optimize many parameters at the same time, which may be conflicting or independent. Improving one design objective can very likely be detrimental to another.

Some optimization methods can be stochastic, meaning that each time you perform the optimization you will likely get a different answer. Keeping track of these different answers gives us a zone where solutions work and another zone where they do not. The division between the two is known as the Pareto Front, named after the Italian designer Vilfredo Pareto (fig.66).

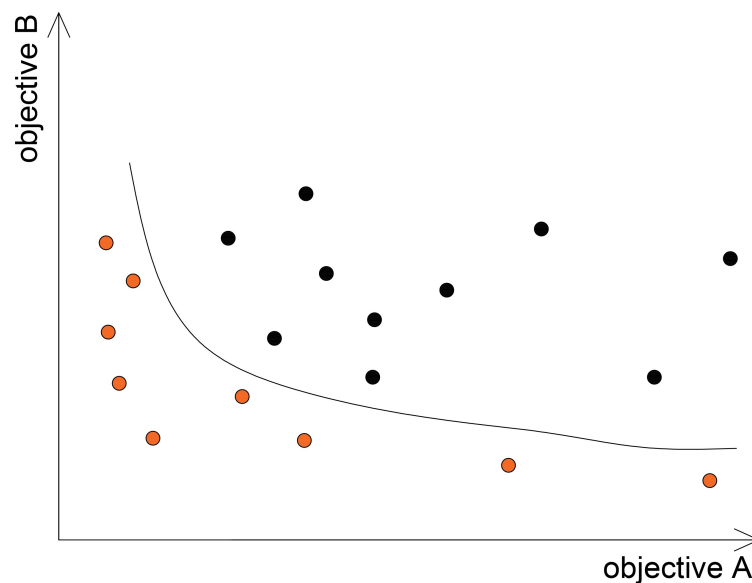


Figure 66 - A representation of Pareto Front for multi-objective optimization

It is not always clear how to weigh the fitnesses of different objectives. Examining the Pareto Front can help you make decisions—what the right compromise is—or it can even suggest solutions that have not yet been explored.

If the optimization process is yielding improvements, there is not much reason to stop, but you usually will not see significant improvements after a while. On the contrary, there is generally a lot of progress in the early stages, and then the improvement drops off until it becomes negligible (fig.67).

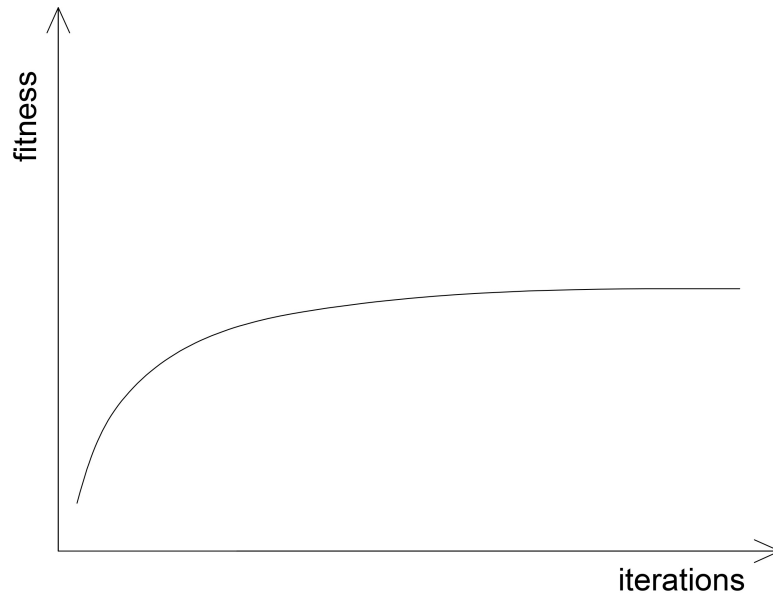


Figure 67 - An example of the fitness progress during iterations

The curve in the graph above (fig.67) represents a somewhat optimistic nature of what happens during optimization. Typically, you will get long periods of no improvement, followed by a sudden jump to a new fitness. However, if there has been no improvement for a while, have you stalled, reached your limit, or does the program still need time to take the next step?

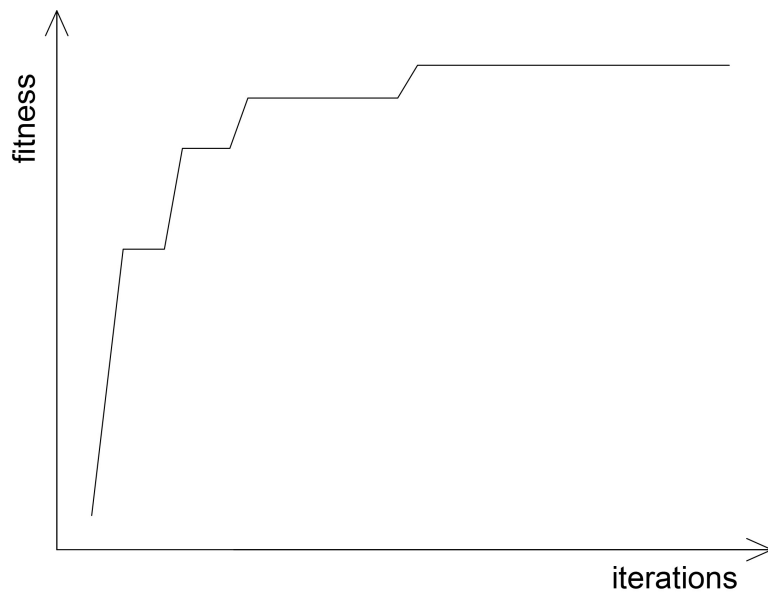


Figure 68 - A more realistic example of the fitness progress during iterations

The question in this case is: How long does it take to be convinced to accept that there are no improvements until you end the analysis and stop the optimization process? You can choose a number of iterations of the process, but if this number is low, you will still be in the phase of improving the results. Therefore, a longer time is recommended (of course, within the possibilities). Let the program run all night or over the weekend and then stop it.



Figure 69 - A woman sleeping while the computer is working (image generated by DALL-E)

Before undertaking a computational optimization, first consider these questions:

1. What is the best way to objectively measure the design fitness of a building?
2. How can we reduce the design space without affecting the reliability of the optimization process?
3. What is the fastest way to explore and sufficiently utilize the results in the design space, while avoiding both premature stopping of the process and excessive time consumption?

Some may worry that they cannot account for everything in their optimization, and so they do not optimize at all. A partial optimization is better than no optimization at all. Do not worry that the client will ask for changes to your design: they will start from a better point than the starting point.

It's also good to remember the principle of “sufficiency”, during those moments when you try too hard to achieve the final improvements to your design. One of the key points of structural design is knowing when close enough is good enough.

Third, we cannot ask the computer to give us the “best” shape. If we ask the question in the right way, it can give us the lightest shape, or the cheapest, or the shape with the least energy consumption, etc. Make sure you ask the right question.

Therefore, the “best” design does not exist. There will be the lightest and cheapest design, the lowest carbon and energy-efficient, the most recyclable and the most recycled, and all of

these designs will be different. They will also be resistant and durable designs, but these qualities we need to complement, not maximize: something safe enough is safe. There will be beautiful and ugly solutions, but they are harder to measure and even harder to deal with.

In addition, the objectives influence each other; the cheapest structure may lead to a building that is more expensive to build or use; the most efficient building may have stability problems, etc.

Does this mean we do not need to optimize? Absolutely not! Some projects are clearly and unjustifiably over-dimensioned. Improving the overall shape, for example, can yield significant savings without compromising stability, and sometimes a more resilient structure can be more economical. Construction is responsible to a considerable extent for the damage it causes to the environment, and it is our duty to reduce this.

It is our duty to design what is safe and resilient, durable and elegant, and that the final product does what it is supposed to do and more.

Knowing when to stop

"If you don't know where you're going, how will you know when you've arrived?" (Carroll, 1893) [137]

When optimizing, you are searching for the global optimum: the best solution. But how do you know when that point is reached? Some optimization methods have a defined endpoint, such as Gradient methods, which make no further progress, or Simulated Annealing, where the temperature drops below a limit. Other optimization methods are open-ended, such as Genetic Algorithms or Particle Swarms.

If you do not know that you have reached the optimum, will you continue the process indefinitely in the hope of getting something better? Of course not: an optimization that does not give an answer is worse than one that never started: you have not gotten an answer, but you have spent a lot of time and energy. When optimizing, there can be uncertainty: have you found the most optimal value or just an optimal value? In addition, the calculation can have a cost, whether in time or money: the method on your laptop may be free and slow, but on a "cloud server" or with certain programs you will have to pay to use it. You do not have the luxury of endlessly repeating the optimization process in the hope of finding something better. So when should you stop?

The problem we have in this case is called the Stopping Problem, which has challenged mathematicians for a long time. One option is to specify how long you want to extend the optimization process; when the time runs out you stop the process and get the results. The

problem with this is that, due to insufficient time, you may have found a local extremum and spent a lot of time on a bad solution.

Ted Hill describes a solution in a hypothetical experimental case study. In Hill's scenario, suppose you are looking for a new house and you need to live somewhere within a certain time limit. There are probably hundreds of different options to choose from, and you can spend a lot of time and energy looking at all the alternatives. The problem is that you never know if there is a better house/apartment that you could afford to buy—and that any of the ones you rejected will be the best possible. How will you decide that you have found “the right one”?

Interestingly, computer heuristics suggest that to maximize your chances, you should reject the first approximately 37% of the options available, then choose the next one that is better than all those you have seen so far. This is not a perfect formula. You might have seen an ideal option during the rejection phase and, as a result, continue to reject all the options until the last one, which has very little chance of being the ideal one. On the other hand, you might be unlucky and only get bad options at first, leaving you with the option that is slightly better than they are, later.

How does this apply to optimization problems, where we can mark the best options and always have the opportunity to return to them?

You may have a time limit or a budget to perform the optimization process, or you are performing an optimization that always gets stuck in local extrema. As a result, you have to restart the optimization process each time, hoping to get the best result every time, but how many times will you perform this process? One answer is to set yourself a maximum number, mark the best answers of each optimization analysis, repeat the process 37% of the maximum number of times, and keep repeating it until you get an answer better than the results you got so far. The worst that can happen is that you have to perform an optimization for a full cycle of this method, but chances are that you will find the answer in a shorter time.

5.2 Optimization as Mediator: Dealing with Humans

Regarding negotiations with clients, Alvaro Siza recalls that this discourse can sometimes be very conflicted and in that case the architect has two choices: “he can simply acquiesce to the client’s ill-informed criteria and desires, or he can attempt to arrive at a resolution by challenging the client’s prejudices every step of the way.” [30]

What if these are not the only options and you can actually achieve more from these meetings?

I have previously explained that participation is contingent. Sometimes by seeking participatory design, designers make the design worse. However, as long as we accept the contingency and see these meetings as opportunities to advance the design, what is left for us is in fact the possibility of negotiating in these meetings.

Then there are the others, who will never be part of these tables and it is the responsibility of the designers to take their requests into account. Of course, this process also does not have a solution manual. How can it have when the real owners of the project—the people who will deal with the structure during its life—usually never have a voice during the design? All that structural designers can do is assume certain things, but the final judgment, if there is a sense of belonging that comes from the structure, will come from its users or the people who deal with it in the future. And we, as professionals, are not very qualified to think in terms of the users of structures. The solutions that I will offer below are practical and certainly do not have a manual. They are heuristics that, like traffic lights that regulate traffic without determining routes, simplify the designer's work, but in no way remove the requirements for reasoning and situational thinking. In Jeremy Till's book, *Architecture Depends*, he tells of a case in which an architect had the idea to make quick sketches during a meeting with a client and use them as tools for negotiation. Of course, he himself could not draw the sketches at the same time as he spoke to the clients. Fortunately, for him, he had a very talented student who had a remarkable facility for quick, but cogent sketches. Therefore, they collaborated and, when they went to meetings, it was usually the two of them. While the client and architect discussed problems of function, site, and cost, the student would sit quietly at the back, picking up hints from the meeting such as “‘it would be most efficient to have the entrance on the lake.’ ‘The sun angle gives a curve here as the optimum solution.’ ‘The plot ratio says go high.’” [8] Picking up these hints, he would turn them into suggestive sketches. At the end of the meeting, the architect would present the drawings to the client. “You could knock the client over with a feather. It was normally a done deal.” [8], he says. In Till's book, this example is presented with a negative tone, just as negotiations are accompanied by the same approach in design theory writings. This is not to say that they are inherently bad. Of course, intentions can be bad, and negotiations themselves do not add value to the design. They are simply a means to an end, and a very important one if you want

to protect structural values, while grasping some others during the meetings. What negotiation achieves differently from mere participation is that it provides an opportunity to go beyond the client's requirements. The problem is that the assertion for the ethical guidance that the design activity has today is to meet the client's requirements. Their requirements, on the other hand, especially in the private sector, are often short-term, opportunistic, and potentially exploitative. It rarely happens that the client understands the long-term benefits of the structure for the well-being of those who will face it years later or the environmental responsibilities. This is also driven by the demand of the market, which is geared toward maximum development in the short term. Serving the client's requirements one by one in these cases does not mean at all achieving a structural design in the service of people. In fact, it is the opposite: it can be unethical.

A successful structural design regarding ethical design occurred around 2010 in Vlorë, Albania. The owner of a bar asked a construction firm to deal with the demolition of the structure of a pier, which was the symbol of the city of Vlorë. The pier's structure was built long before the bar, around the 1930s, and it was a cultural mark for the city—it had a community of its own, passed by different generation, made of teenager divers, kids who wanted to learn how to swim and fishermen. The reason for the demolition request was that fishermen who went at the pier, passed by the bar and, according to the owner, the smell of the fish bothered his customers and, by demolishing part of the pier, no one would go fishing. I do not have a project sheet to show you, because the construction firm refused to initiate a project for this case, which, in the concept of design ethics that we have discussed, it was actually one of the best projects completed. The design and implementation firm refused to demolish the pier and I quote the words of its administrator: “The pier of the city of Vlorë is a symbol of this city. I myself grew up and learned to swim there. For this reason, I absolutely cannot participate in its demolition.” Unfortunately, another firm took over the demolition of the pier and thus the demands of the bar owner were met—which in terms of ethics according to design codes would be called a successful project, as the firm served the client's needs.

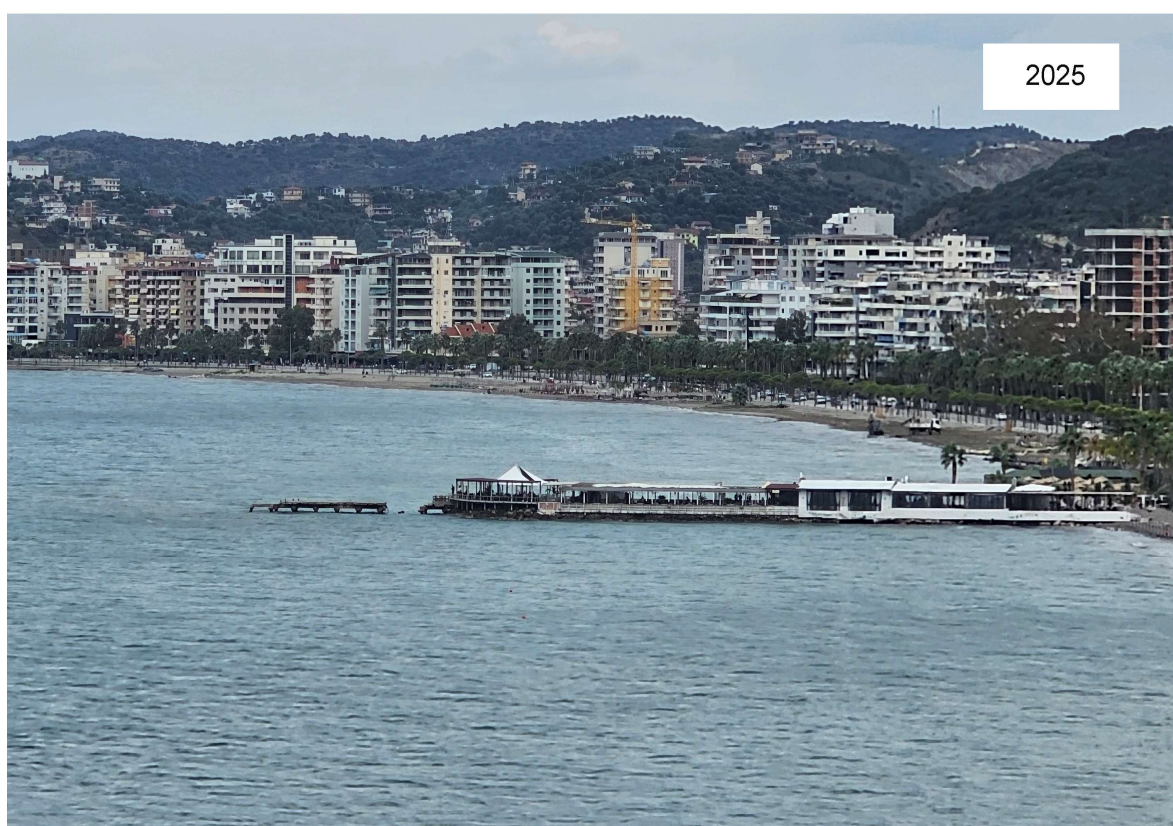
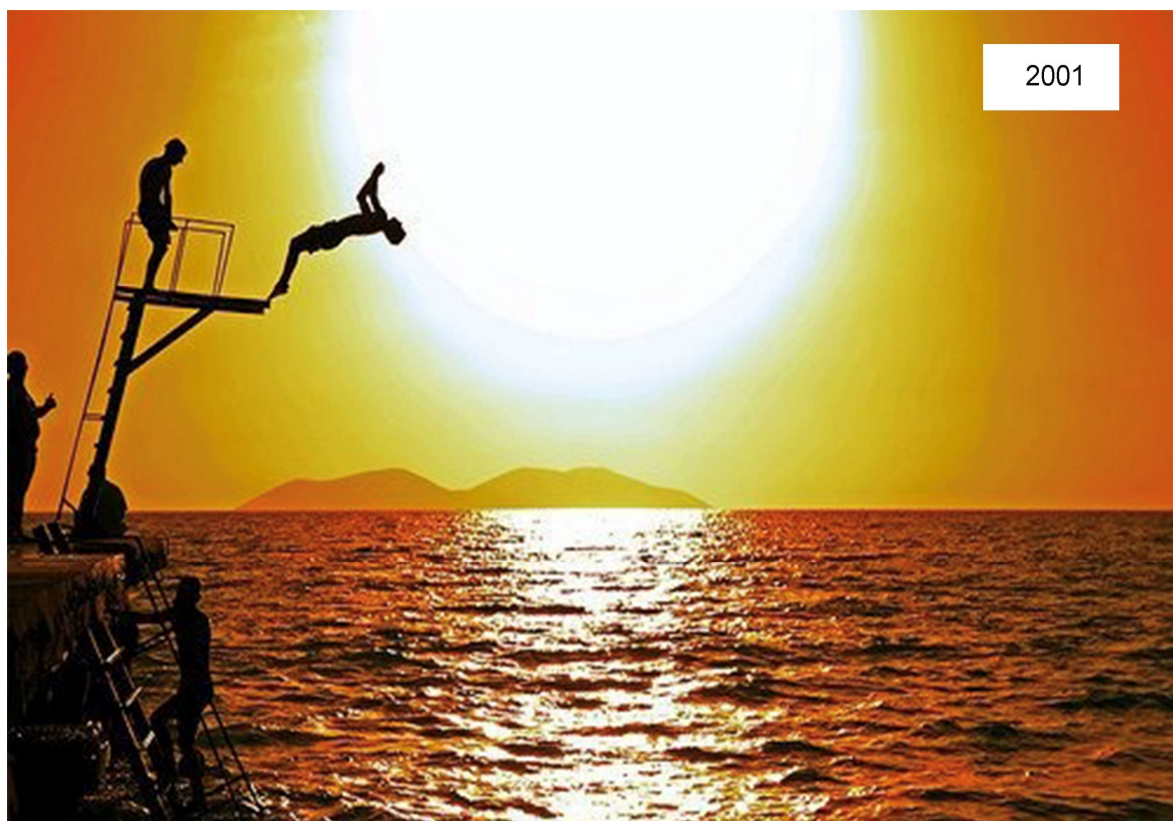


Figure 70 - The pier “Moli, Vlorë”, before and after its destruction

I like to think that there is always the possibility for structural design to go beyond the basic requirements stated by the clients, while also taking into account (why not) their own requirements, however absurd they may seem. It is precisely the ambiguous nature of this discussion process in the conceptual phase that allows for suggestions and accepts ambiguities that should encourage designers to arrive at solutions that carry design value. This is not a call to compromise client demands, but according to Till, he emphasizes that no single solution can claim absolute correctness in addressing demands for short-term efficiency. [8] This openness, he suggests, allows designers to maximize spatial alternatives in ways that generate environmental, social, and experiential benefits. [8]

“If in doubt consult your conscience”, writes Bauman, “moral responsibility is unconditional and infinite, and it manifests itself in the constant anguish of not manifesting itself enough.” [141]

His approach to ethics puts us with our backs against the wall and asks us to hold ourselves accountable for our actions, rather than addressing them to a manual of instructions. According to this approach, there is no manual of instructions for designing structures with value, because design is contradictory, dependent and situational. However, this does not mean that design is “an anything goes” process. On the contrary, the fact that we do have the potential to confront problems with directive manuals and to come up with formal solutions makes the responsibility of structural design ours alone. You do not have to solve all the problems either. As Till says, “Imperfect ethics is not a contradiction in terms but an aspiration, because right at the heart of that term is a responsibility for the other and the appreciation of the differences of the other.” [8] Hans Jonas shares the same opinion when he says: “the starry-eyed ethics of perfectibility has to give way to the sterner one of responsibility.” [142] The structural designer should at best make forms that allow people as individuals and as groups to express themselves by improving their life. In this way, the designer expresses his values by making it possible to express the values of others. Only then can the fact that another structure is being built, be forgiven. If design ethics is not the service that structural designers want to provide, then what other choice do they have? Today, structural designers only work for investors. There will come a day, with the advancement of computers, when they will not even work for the investor anymore, since for the latter it is enough that a structure is, first, as marketable as possible, and second, that it meets the conditions for construction. If both of these—technical and the marketing aspects—can be done through the computer, with pompous images and with technical details and precise calculations, then the marriage between investors and structural designers will end (not by consensus, but by the betrayal of the investor with the computer).

To discover the true needs of others means to expose and accept their right to have things and their right to express themselves. It means to provoke direct participation and to measure your values as a person with those of others. It also means to question all the traditional

values of design, which, since they are not built for participatory design, must be reviewed and reformatted when participation becomes part of the process, releasing all the energies that have not yet been explored. In the case of residential housing, for example, traditional design has a big ethical problem. According to it, to design for wealthy social groups means to plan with high standards, while for poor social groups, to design units that belong to a lower stratum. Design for the rich must follow innovation, the avant-garde, while design for the poor must follow the minimum of requirements and standards, as if the needs of people of the two groups are different.

When the project is finished and the structure is erected, the investors and designers leave the stage and the object, the users and those who encounter it take the active role. For this relationship to be fruitful, like any relationship, it is important that both parties go through a process of transformation and acceptance. The object changes with the transformations that the user imposes on it while the latter adapts his needs to the potential offered by the structure. A traditional structural project functions with the idea that only the second possibility is allowed. However, in the second case, the users are forced to adapt to the structure as if they were inside a cage without being able to modify it. Any attempt to change the structure is in fact illegal and punishable by those who seek to guarantee complete order. All this tension can be addressed at the design stage by encouraging participation.

The Prime Minister of Albania, Edi Rama, after finishing his presentation on the Vlora Airport project, amidst the applause, stopped to listen to two women in the crowd. “Many beautiful photos. If it is fixed like this, it will be salvation for our city!” said one. “Congratulations, Mr. Prime Minister, for this opportunity you gave...” shouted the other, while the applause created a cacophony and the sentence never ended. Therefore, the participation was completed and the project was put into implementation. What I want to show with this extreme example is that, under the guise of inclusiveness, the same old patterns of top-down power repeat themselves, defeating the expectations of participating citizens that they can get something more than what is offered to them, thus distancing them from the real processes of spatial production. Till understands it very well: “It is the unequivocal acceptance of participation as a better way of doing things that is both its strength and its weakness.” [8] The strength aspect is the fact that it can encourage all affected parties to be involved in the project, while the drawback is also that because there is so much inclusiveness, the parties never manage to raise their voices for their interests because they never manage to be adequately represented in all that conglomerate of different values. Participants bring to these meetings a skepticism that anything may change in their individual lives. How can anything change, indeed, when there are so many parties involved in this project? Every request will seem selfish. Or worse; it will seem so unattainable that it makes participants come to the meeting with a sense of distrust and not ask for anything at all.

When people outside the design discipline are involved in a project, their presence exposes issues that professionals often prefer to overlook. The participation of users of structures tends to bring to the table desires and concerns that differ from those of investors, who typically focus on cost, construction time, and efficiency. In contrast, users of these spaces may prioritize comfort, convenience, or personal routines, and these priorities complicate the designer's task. Participation can even conflict with design norms, because the values that guide designers do not always align with those expressed by non-experts. Therefore, relying too heavily on public input increases the risk of calling current design norms into question. Another difficulty that arises is that communication between professionals and non-professionals is never easy because of the technical vocabulary on the part of professionals. As a result, specialists are usually in control of the progress of discussions, setting the terms and shaping the outcomes of participatory sessions.

Participation is often described as the creation of a shared understanding, but this assumption has two challenges. On the one hand, shared understanding implies that agreements come effortlessly, as if decisions arise naturally without disagreement or reflection. On the other hand, genuine cooperation requires practical reasoning. The idea that people can reach a common ground presumes that their judgments are based on a universal good, which consequently requires participants to find that solution that is best for all parties. Such assumptions limit the ability to address differences in preferences and goals that individual participants have. When common sense is treated as a set of fixed intellectual rules rather than as an outcome of lived experience, the design process becomes detached from everyday social and cultural life. As a result, what should be a grounded, human form of understanding becomes formalized and abstract, distancing design from the complexity of real situations.

For this reason Till suggests that “instead of seeing participation as the move towards the establishment of common sense, it may be better to posit it in terms of making best sense.” [8] This takes the responsibility of objectivity and impartiality off our shoulders. Instead, we have the responsibility to protect those design values that do not yet have “owners” during the project phase. Even Charles Taylor recognizes that the practical aspect of “best sense” is the only one that can be achieved and in fact offers a more realistic direction towards “the best structural project” [143]. This approach allows us to accept three things. First, that there is no ideal all-encompassing solution. Second, that others are involved in this process and by default design must adapt to speak their language, not a language that only professionals know. Third, participation, as every aspect of design, is also contingent, which means that there is no equal participation. Despite the contradictions that come from the different design values that are faced, the discussions have an intentionality. This necessarily leads to an acceptance of changes rather than the imposition of false equality. The good thing in this case is that, by accepting these changes during the design, some potential changes that users will ask to make later without having the opportunity due to strict regulations, can be addressed from the beginning.

5.3 Optimization as Design Tool

How to set a computational optimization?

The mathematical optimization formula is:

Minimize $f(x)$

Which depends on $g_i(x) \geq 0 \quad i = 1, \dots, m$

and $h_j(x) = 0 \quad j = 1, \dots, k$

and $x_L \leq x \leq x_U$

While:

x = a series of designing parameters

f = the function value that is depended on parameters x

g = inequality conditions (certain parameters x must be larger than or smaller than a certain value)

h = equality conditions (certain parameters x must be equal to a certain value)

x_L and x_U = the upper and lower boundaries that parameter values can get (which are also inequality conditions).

To sum it up:

Minimize $f(x)$, which depends on $x \in \Omega$

Where $\in$ means that elements are inside the set Ω (which is the set that includes all the numbers that satisfy all the above conditions).

In structural design, computational optimization is the minimization of a parameter (for example, cost or construction time) as long as it does not violate the initial conditions. For example, one of the conditions that should not be violated is that every part of the structure must be resistant enough to carry the loads. Optimization can be simple, such as selecting the lightest beam section, or complex, such as choosing between different facade shapes or the overall shape of the building. It can be done to select the typology of the slab or the shape of the truss. It can be to reduce the cost of the structure, or to reduce the amount of energy consumed in a building from its construction to its demolition. You can optimize the design of a bridge or you can optimize its location. It means achieving your goal with “less”. At this point, we need the computer to help us sort, prioritize, and filter all the possibilities so that we can decide which answer is best.

For example, let us consider the optimization of a reinforced concrete slab. We know the conditions, which are that the slab must cover the span while resisting the forces. The constraints will be that the slab must be resistant enough to withstand the loads (strength $\geq$ load), and not deform too much (deflections $\leq$ allowable limit), and, since I have already said that it will be a concrete slab, it must be a standard section of those that can be built in practice. Another non-equilibrium condition is that the structural element must be stiff enough so that there are no perceptible vibrations.

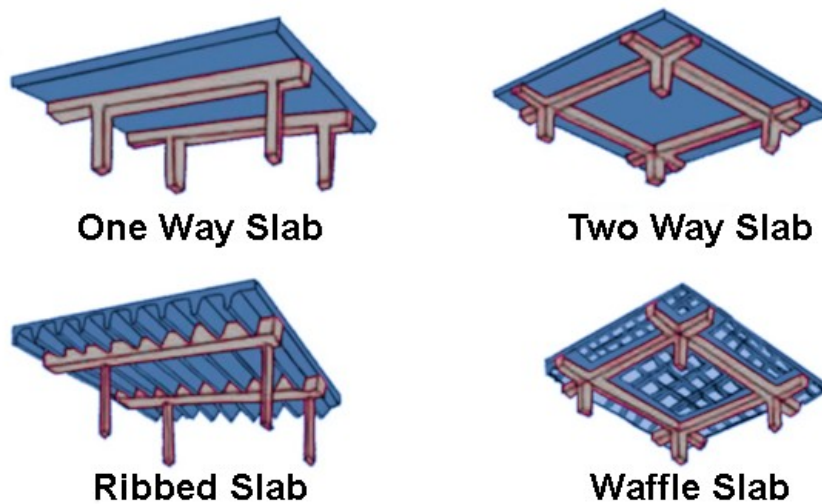


Figure 71 - Typical slab typologies

Finally, I can also choose in which aspect I will optimize the slab. If I want to hide the beams in the slab, I can ask for the depth of the beams to be equal to the depth of the slab, so as not to install additional formwork, which will reduce construction time. If I am building my own house, I may have the objective of choosing the cheapest section, or, if there is no special requirement, I can choose the lightest slab, which would reduce the loads. Satisfying different and multiple objectives is difficult. The lightest slab will not also be the shallowest slab and vice versa. If your objective is the shallowest and lightest slab, then the selection of the section will be a compromise between these two. Sometimes it is a good idea to set the criteria in a hierarchy, for example: if you have two slab sections with the same depth, choose the lighter one.

Sometimes optimization can be simple. If I have a statically determinate structure, such as a unidirectional concrete slab supported at two points, for which I have a good idea of its self-weight, I can easily find its bending moment, shear forces, and the required stiffness. It is enough to choose the lightest slab that satisfies the conditions in the serviceability limit state and in the ultimate limit state. Optimization becomes more complicated when different parts of the structure interact with each other. This can occur when I have a frame with many spans, where the objective may be to choose the sections of each element so that the final weight of the structure is as light as possible. In any case, increasing the size of the structural element to satisfy the conditions will increase the stiffness or weight, which, in turn, will increase the forces and moments in that element, which will require the elements of the floor below it to be even larger.

Other complex problems arise if I seek to optimize costs. Non-standard shaped bricks, used as infill for T-beams, are expensive, which means that using slabs with large beam dimensions can sometimes be a cheaper solution. Likewise, larger reinforcements have a lower cost per weight of steel, as they require less work to shape in the factory. Construction

cost does not have a linear relationship with material quantity. The lightest designs are rarely the cheapest (a reason for that is that their joints are often complicated). On the other hand, if I want to optimize for environmental impact, the results will depend heavily on the materials used, which, in turn, will affect the weight.

Design optimization is complicated, as there are a number of choices to make, each of them likely to have a significant effect on other aspects of the construction. For example, specifying fixed ground supports will result in smaller concrete sections above, at the expense of larger foundations.

Such optimizations can be complex to solve and often require nonlinear methods to find the final answers. Computers explore many possible options in a short time.

Optimization can occur at any stage of the design process. During the design concept, you decide on the shape of the building, the type of structural system, the type of materials and the construction method. Optimization at the detailed design stage then allows you to improve the solutions to some extent while targeting some objectives.

Structural optimization is nothing more than finding the best design from the alternatives you have, preferably in the shortest time. We want to see every possibility, but there are, if not an infinite, an extremely large number of them; a control that lasts indefinitely and is exhaustive is rarely a good option for structural designers. The design space is essential for optimization and can consider things like steel or concrete, beamed or beamless slabs, column spacing or main beam directions, and even the overall shape of the building. Defining exactly which design aspects will be investigated and which will not be considered is a key step in any optimization.

Design spaces have one dimension for each parameter, so, for example, if there are 100 sections to choose from for a concrete slab, the design space has one dimension with 100 points along it. By the same logic, if there were two different slab typologies, then the design space becomes two-dimensional with 100x100 options, and so on. Although reality is three-dimensional, the design space is usually multidimensional. The point here is to find where the optimal design solution lies in this space. The smaller we make the design space, the more chances we have of finding the most optimal value from it. But be careful: while making the design space too large will slow down the process and, most likely, prevent you from finding the answer, making it too small can risk missing the optimal solution. Therefore, it is an important part of optimization to, first, optimize the design space, making it as small as possible, without compromising the primary requirement to give good results.

Another thing to consider are the dependent and independent parameters. The section sizes of the slabs are dependent on the bending moment, which is a consequence of the load quantities, which are independent of the beam and column weights. This means that we do

not have to include other structural elements when optimizing the slabs. Alternatively, if we had a beam in flexure, where the distribution of the bending moment depends on the weight of the slab, then we would have to include the section sizes of the slabs in the design space, which would complicate the solution.

How do you use the design space to optimize your design? First, you need to decide what you mean by “optimization” for that particular case. It could be lighter weight or construction cost, or something even more specific to the project. Then you need to assign a measurable value so that you can compare it. You can think of the design space as a terrain, where each point in this space has a height that is related to how optimal that point is and, consequently, the location of the most optimal point is the highest point (or lowest point, since optimizations are usually about minimizing values).

Imagine that you need to find the highest point of the mountain in the state where you live. The problem is that you do not know where to start and you have no idea what the terrain is like. How do you do it? This is exactly the problem that everyone who wants to solve an optimization problem faces, except that the geography of the design space usually has more than three dimensions. Another problem is that there can be many peaks, so we have to be careful not to find a small mountain peak and get stuck there, ignoring the higher peaks. How you explore the design space to find the highest peak is the essence of optimization.

The example below shows the design space of a reinforced concrete slab. I defined the constraints (it should not collapse in bending, nor from shear forces, etc.). I also used my experience and the project requirements to reduce the size of the design space until it becomes manageable. For example, I know that, if I choose ribbed slabs, it will have a depth of 30 cm, since the slab bricks are 25 cm high and the concrete slab on top cannot be less than 5 cm because it must be deep enough to place the struts, longitudinal reinforcement and cover. In addition, if the slab is to be solid, it will have a thickness greater than the span/20 (pre-dimensioning conditions for allowed deformations) and greater than 12 cm (a recommended constructability minimum), and will preferably be an integer.

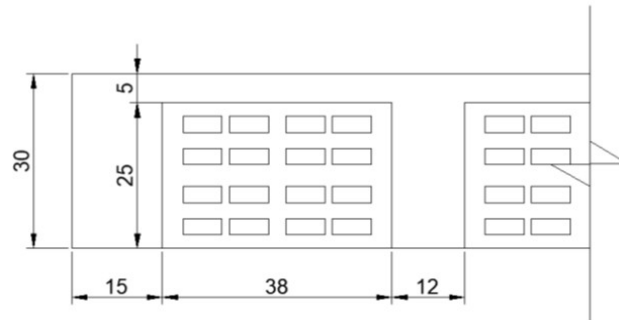


Figure 72 - Red clay brick for ribbed slabs in Albania

Moreover, I know which type to choose depending on where I live. In Albania, we use slabs with one-way or two-way beams, or solid slabs, so I know that the section I will choose will depend on these typologies. I have reduced the size of the design space considerably, but I can reduce it even more. At the company I worked for, the designer wanted us to choose solid slab sections from 12 cm to 20 cm. The reason was that the slabs should not be too thin because they would vibrate, but not too large because we would lose a lot of floor height, as well as add weight to the building; it also meant that we only had about ten section alternatives that we could choose.

Design space:

1. Solid slab 12 cm
2. Solid slab 13 cm
3. Solid slab 14 cm
4. Solid slab 15 cm
5. Solid slab 16 cm
6. Solid slab 17 cm
7. Solid slab 18 cm
8. Solid slab 19 cm
9. Solid slab 20 cm
10. Ribbed slab with ribs in x direction 30 cm
11. Ribbed slab with ribs in y direction 30 cm
12. Waffle slab 30 cm

However, the simulating design space, the one that the computer will actually explore, is way larger than that. It involves all the possible combination between span directions, slab geometrical features, rebar geometrical features, material classes, and the construction costs/unit of different material classes.

The load-bearing capacity checks for the slab are many and complex, but they can all be translated into a single number: the ratio of the applied load combinations by the bearing capacity of the slab must be less than one. For the deformation limits, we can check each section to see if the deformations are less than those that are allowed. Later, I study the fitness problem, which means: how much better is one solution to the problem than another solution, and, consequently, which is the best? This value should be objectively measurable, such as weight or cost, but it should be more than just the smallest values, since the lightest or cheapest slabs are useless if they cannot support the loads. While each possible final solution must satisfy the usual design requirements of a structure, I can tolerate some limitations (but not ignore them altogether) in order to achieve the optimum. It is very likely that the optimum is on the thin line—or very close to it—that separates failure from success, and the calculations for the most optimal solution I will choose should have the opportunity to explore that area. The conclusion from this exercise should be a structure that satisfies all the design requirements.

In the example below, I am choosing to measure fitness as the total slab construction cost. The floor has 23 mini-slabs (which are the polygons bounded by beams configurations).

After using the algorithm, the most optimal section turned out to be a ribbed slab with a 30 cm thickness.

Table 2 – An example of inputs and outputs of an algorithm for slabs typology, addressing their construction cost

	Span x (meters)	Span y (meters)	Cost of two-way RC ribbed slab with red clay bricks/m2
Mini-slab 1:	8.5	8.5	6000 lek
Mini-slab 2:	7.4	7.35	Cost of one-way RC ribbed slab with red clay bricks/m2
Mini-slab 3:	1.7	1.5	5600 lek
Mini-slab 4:	9.3	9.7	Cost of steel Ø 6 - 10 mm/ton
Mini-slab 5:	1	4.05	127686.5 lek
Mini-slab 6:	3.3	2.65	Cost of steel Ø > 12 mm/ton
Mini-slab 7:	1.8	2.7	123074.87
Mini-slab 8:	1.8	4.05	Cost of RC solid slab/m3
Mini-slab 9:	1.8	2.65	26809.38
Mini-slab 10:	5.5	4.5	The algorithm answer:
Mini-slab 11:	5.5	4	Mini slabs 1, 2 and 4 should be done with two way ribbed slabs. S1: Reinforcement in the longest span direction: 2φ10, above, 2φ14 below. Reinforcement, direction in the shortest span: 2φ10 above, 2φ14 below. S2: Reinforcement in the longest span direction: 2φ10, above, 2φ12 below. Reinforcement, direction in the shortest span: 2φ10 above, 2φ12 below. S4: Reinforcement in the longest span direction: 2φ14, above, 2φ14 below. Reinforcement, direction in the shortest span: 2φ12 above, 2φ14 below. All the other slabs should be done as one-way ribbed slabs, with ribs along the direction x. Reinforcement: 2φ10 above, 2φ12 below. Stirrups φ8/20, moulding bars φ8/25/50. t = 30 cm
Mini-slab 12:	5.5	4.5	
Mini-slab 13:	5.5	4.5	
Mini-slab 14:	5.5	4.5	
Mini-slab 15:	4.5	5.5	
Mini-slab 16:	5.5	4.5	
Mini-slab 17:	5.5	4.5	
Mini-slab 18:	5.5	4.5	
Mini-slab 19:	5.5	4.5	
Mini-slab 20:	5.5	4.5	
Mini-slab 21:	5.5	4.5	
Mini-slab 22:	5.5	4.5	
Mini-slab 23:	5.5	4.5	
other parameters include: concrete class, steel class, cover, ribs dimensions, slab thickness, red clay bricks density, live load			

In case I want a script that rearranges the spans according to a set tolerance (say by 50 cm each), seeking to minimize the slab construction cost, I can use the optimization methods. Below is an example that uses Simulating Annealing to find the optimal slab typologies and spans in order to have the least possible construction cost (fig.73).

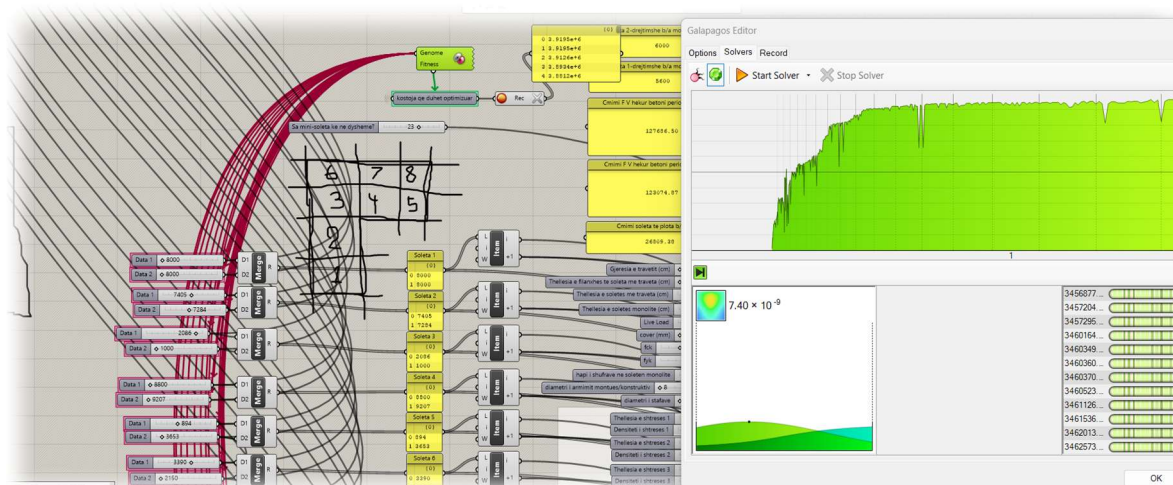


Figure 73 - Building the optimization process in Grasshopper

For linear problems, the first choice from optimization methods are the deterministic methods. They are called like that because they always give the same answer. In general, they are faster and more accurate, but there are cases in non-linearity where they are limited and do not give good results. The Gradient Descent is one of them.

The Gradient Descent method can be so simple that you may have used them without realizing it. If you are designing a concrete beam, you will find a required reinforcement area, and then you will choose a number of steel bars of a certain diameter whose area is closest to that required (limited by the minimum and maximum reinforcement, as well as the minimum distance between the bars). What you are actually doing is ranking your options and then choosing the smallest possible one that satisfies your requirements. A gradient descent method on a computer works with the same logic.

If it were to choose a rebar diameter, it would take all the available diameters, rank them in ascending order depending on the objective (by surface area value), then select the one with the lowest value for control and continue until it finds the first one that meets the conditions. This way, you know that you have found the smallest rebar diameter that fulfills the requirements.

One of the biggest challenges of optimization in building design is that, for most problems, there is more than one extremum; another is that the path to the top is not always clear. If you look at the thickness of reinforced concrete slabs versus slab cost, you will see that the line that comes out on the graph (fig.74) is not at all smooth.

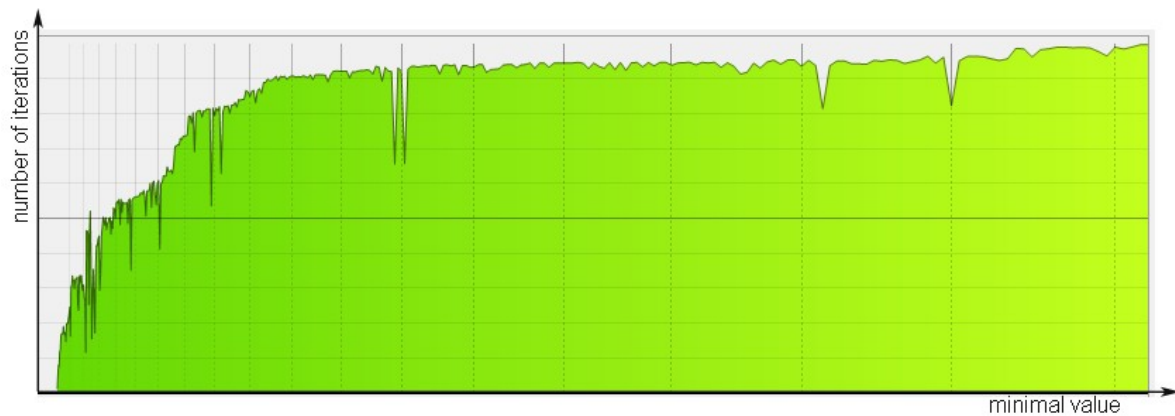


Figure 74 - Relation of “minimal slab construction cost/number of iterations”, using Simulated Annealing

If only the solid slab typology is considered, you can check starting from the shallowest depths and moving forward until the resistance conditions are met, since the direction leading to the optimal weight is clear. When considering different slab typologies, the situation becomes more complicated and it may be better not to always consider the sections with shallowest depths because some slab typologies with greater depths may have lower costs.

Another problem of this method is that it can struggle when the slope is not enough. If you start from a flat area, it is difficult to determine the direction of the slope. As a result, you can perform several checks with the gradient method, starting from different positions, and choose the best of the best.

The gradient method is good when the design space has only one extremum and has a relatively smooth slope. However, what if the design space is more diverse and has several extrema? Even a simple problem with different types of slabs, such as the one discussed above, has several extrema. If you were to use the classical gradient method in this case, it would stop as soon as it reached any local extrema. How do we overcome this shortcoming? One option is to use stochastic methods. We will explain some of them below.

Deterministic methods should normally be your first choice, but, as we said, there are times when they do not give good solutions. When this happens, it can be a good idea to add some random values to your method. This may seem strange if you have been used to applying rigid algorithms and formulas all your years as a student: “These are the formulas, these are the values, apply the formulas and you'll always get the same answers.” Stochastic methods have an element of randomness to prevent the method from being stuck in a local optimum.

Simulated Annealing is a more refined gradient method, inspired by the annealing and cooling of metals. With the classic gradient method, you would check adjacent points in a design space and choose the next point to be attached from those points. Simulated Annealing uses this idea, but also randomly chooses a point at some distance for comparison. The distance is controlled by the “temperature” parameter, which gradually decreases over time during optimization. As a result, the transitions from point to point through the design space are made in large steps, at first, and as the temperature decreases, the transitions gradually become smaller. You can also control this temperature change, depending on the success of the method in finding the best values: increase the temperature when you are not satisfied with the solutions and decrease it when you do not want a radical change.

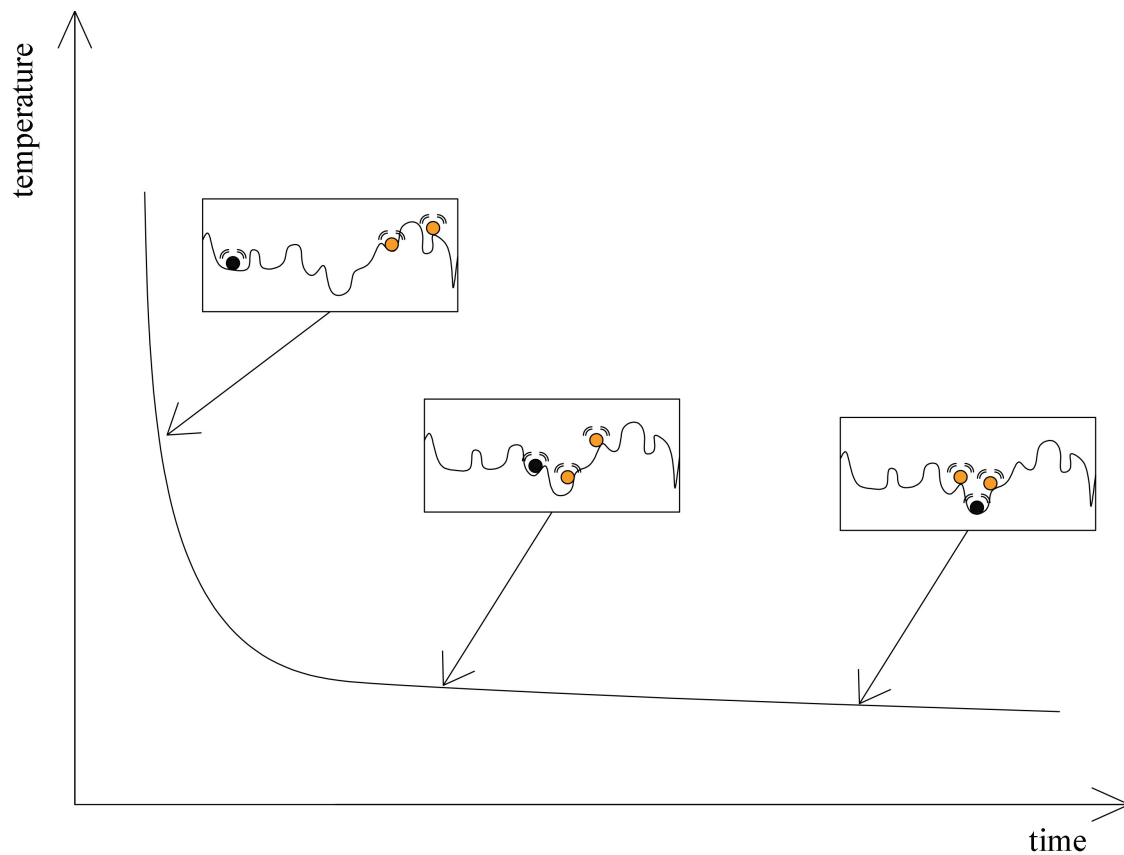


Figure 75 - Simulated Annealing explained

If you were to use Simulated Annealing to find the highest point in Albania, it might start with steps of perhaps 200 meters or so to test different locations. For each step, there would be a gradual decrease in the step size until, fortunately, it finds Mount Korab instead of Dajti, Tomorr, or some even smaller mountain. In addition, to make sure you have arrived at the best solution, you could start from different points or run the optimization analysis several times and choose the best result from all cases, using Ted Hill’s method.

An example of using this method is to search for the most efficient geometry by moving the node positions. At the beginning of the analysis, there is no information about how ideal the

initial geometry is, so the temperature parameter is high, giving us large dimensional changes. As we approach the ideal, the changes become smaller, until we reach a satisfactory conclusion. As a result, the process can start by initially going through coordinates with a step of about one meter or more and, gradually, reducing the step to a minimum of one millimeter, say, to “perfect” the geometry of the structure.

“It is not the strongest of the species that survives, nor the most intelligent. It is the one that is most adaptable to change.” (Megginson, 1963) [6]

When the design space is highly non-linear, Genetic Algorithms may be a better choice as an optimization method. In a Genetic Algorithm, you first need to describe aspects of the structure's parameters using a binary code (with two types of characters) such as “DNA” or “genotype”. The concrete form of this genotype will depend on the problem: for example, in a study of possible bracing positions on the facade of a tall building, each character might represent a diagonal in one direction, in one plane. If this diagonal is placed, it is represented by the digit 1, while, if removed, it is represented by 0. Another way could be for the binary code (with two types of characters) to be a two-digit number, depending on the numbers to be chosen from a catalogue. Whatever the form of the designation, each genotype will improve the values of the solution (phenotype) that you want to analyze.

You will need to set a population size for each generation of genotypes. For the first generation, each genotype is generated randomly. Once the initial population of potential solutions has been created, each one must be examined to see how well it meets the aims of the problem. This is done by assigning a fitness value, which expresses the degree to which the solution satisfies the criteria you have defined. Solutions that do not perform well are not removed at this stage, but they are given lower scores so that they have a smaller chance to “mate” and produce solutions in the next generation.

The mating process provides solutions that have the combination of the characteristics of their “parents”.

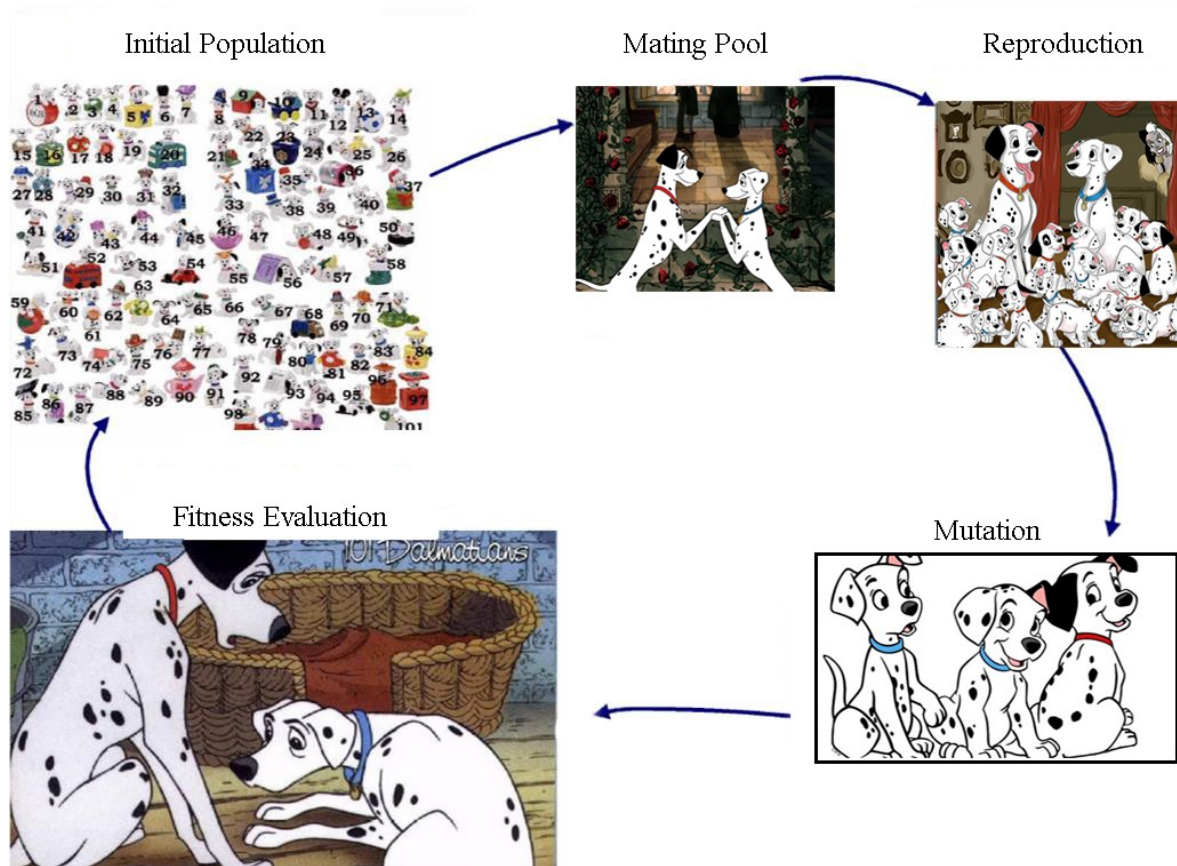


Figure 76 - Genetic Algorithm explained

Simplified example regarding the crossover process (fig.76):

Dalmatian dog 1 genetic code = 11111111

Dalmatian dog 2 genetic code = 00000000

Crossing at point 5 gives

Dalmatian puppies = 11111000 and 00000111

Repeat this with other parents until you have a population for the new generation, and then test it again. Continue repeating the process until, either the overall fitness reaches a certain value, or you have managed to produce a certain number of generations. As expected, the first results will be extremely poor, but working with the few results that have potential will lead to very rapid improvement, at least at first, then, however, the improvement tends to slow down, as the responses get better.

There are several ways to refine the computational process that diverge from how evolutionary methods operate in reality:

1. Make sure that no genotype is repeated in a generation, as you don't want to have “clones”;
2. Keep the fittest individual and pass it on unchanged to the next generation. This method is also called Elitism and saves computing time;
3. Include computational mutations: in random ways, change one of the characters of the genome code (from 0 to 1 and vice versa). The need for this is debatable since crossovers that split genes within genomes will still cause effective mutations;
4. Use “Lamarckism” to refine individual results. Lamarckism is a theory of evolution, now debunked, that believes that changes experienced by individuals are passed on to their genes (i.e., that there is an inherited memory in genes). Although biology doesn't work that way, that doesn't stop us from putting this idea to work.

Genetic Algorithms have a bad reputation for producing results slowly (after all, look at how long it took nature to create us), but they can ultimately yield impressive results for complex problems, although the solutions may need additional improvements.

Likewise, there are countless optimization methods inspired (or not) by nature as well as countless varieties of genetic algorithms or gradient methods. The principle is the same; they all use the brute force of computers to search in a design space for better results. How they search in that space determines optimization methods as well as their potential. Regarding the nature of the problem, some serve for linear problems, some others for non-linear or even highly non-linear problems. Even in this case, the nature of the problem defines the method and it is up to the structural designer to choose which of the optimization methods to use regarding a certain situation.

6. BUILDING A HOME, TIRANË

Chapter 6

6.1 Sensory Motor Skills

The experience that has restored my trust in my sensory motor skills for decision-making was during the time when I⁷ was looking to buy a property in Tirana. As a young engaged man who will build his future and a family in a city in rampant development like Tirana, the reality has been very harsh. Indeed, in the last two years alone, property prices have doubled/tripled. If in 2019 you could get a 2+1 apartment for 70 thousand euros, in 2025, an apartment in the same area, with the same conditions, costs more than 150 thousand euros.

As for the case in question, I had regretted not buying a land property in Tirana, which the former owner of the house that I rented when I was a student had suggested to me. In fact, the two of them—he, a gentle man of 80 years old and his sweetheart wife, in her 70s—decided to show me where the land was and we walked in the dark for about an hour to see it. The owner of the land lived in Iran and had no intention of returning to Albania, but the price he was asking for that land, at that time, was very high. Moreover, my capabilities and my confidence as a civil engineer at that time (I had not yet graduated from university) were low, which made me hesitate and refuse that offer.

Here I was six years later, disappointed by the extremely high offers for apartments in Tirana and the absurd contracts: some owners wanted the money in cash, not in a bank. Most wanted a 100% down payment while the construction had just started, and one even asked me for 50% of the amount when he had not yet issued the construction permit. Some others had much fewer square meters on the property certificate than claimed, some others had no property certificate at all and were selling their property with a “sale promise contract” and some other apartments had been completed, but had scandalous construction works or had microscopic spaces. I called the former owner of the house I used to rent as a student to find out the number of the person who lived in Iran, because I had a glimmer of hope that he hadn't sold the land yet and that, since he lived so many years away, he would make me the same offer he did six years ago. But he didn't remember who I was or the land in question. One of those days, I don't remember exactly where I was going, but I decided to park my car in my old neighborhood, where I used to be a student. It was starting to rain, but it was lunchtime and it would be a long time until it got dark, so I had time to look around. I parked the car and I decided to try walking along the same path I had taken six years ago. I remember that I had only seen the land once and it was dark when I went and it was quite far from the area where I lived as a student, but, as hopeless as I was, I decided to give it a try. I started from what I knew; the direction to the land was at the end of the main street of the neighborhood. Then I would climb a hill and then my memory would fade. To my surprise, as soon as I climbed the hill and saw a narrow passage between two houses, just enough for one person to fit in, my memory was recreated and my body noticed details that had been

⁷In order to render the human experience, this passage is in first-person.

sleeping somewhere in my subconscious for six years. The unarmed view, the smell of humidity, the touch of concrete and fragile memories that were awakened from a moment six years ago. I remembered walking down that narrow street and people waiting in line in front of it, as if they were cars waiting at a traffic light, even though I hadn't really noticed these things six years ago because, after all, I had very little interest in buying the property back then. And here I was again and my body was taking me where I wanted to go! "Now that I remember the narrow street, at least I know there's no turning back! I'll see all the houses down this street until I find the land!", I was thinking. The rain had other plans. However, I remembered another detail. How could I forget it; we had walked at 11 at night through a meadow that was strangely located in the middle of Tirana and I remembered well the feeling when I passed by it because I was overcome with fear that at any moment a dog would come out and bark at us. I opened Google Maps and tried to locate the meadow but in vain. There were some green spaces around but I wasn't able to tell if there were the meadow I was looking for just by watching on the screen. Therefore, I decided to walk again. There were some green spaces on the horizon, and at first glance they didn't tell me anything, but I decided to walk through them with the intention that maybe they would wake up my sensorial memories with some hint. And indeed, when I finally stepped on the right path, the memory and image of the trail I had walked six years ago was built by itself.



Figure 77 - The narrow street and the meadow

I could not explain exactly what details had led me to this conclusion because I did not really have any exact details to refer to, but I could tell that it was the right path. It was clear that I was in the right direction. The next problem for me was where to walk. The light rain was enough to make the meadow path muddy. Anyway, I entered the trail on foot and walked to the end of it, since in my fragile memories I remembered well the feeling of crossing the path. My efforts had rewarded in an instant when I came out across the meadow! I finally remembered that area. I did not know exactly where I was and where the land was, but I felt that I was close! I opened Google Maps, searched for the land, and made a plan of how far I would go before returning to the point where I was (since I knew for sure that the land was relatively close to that point). On the second try, finally, there it was (fig.78)!



Figure 78 - The land where I am going to build our home

After finding the land, with a little effort by asking around the neighborhood, I managed to contact the owner, who still lived in Iran and had not sold the land. Of course, the price of the land was higher (not everything is solved with sensory motor skills). However, it was an acceptable price for the area and for my budget. After all, according to my calculations, it cost less to build a villa + buy that land than to buy an apartment. The experience of that day left me with a good feeling, but deep down I have always known that what nature has offered us with our body, senses, feelings and perceptions in the world is much more than what is believed and explained by modern culture. And really, if you think about it, how do dogs find their home even after being away for hundreds of kilometers? We may have a weaker sense of smell than them, but our senses should not be underestimated at all, especially our ability to transmit emotions and perceive our surroundings. The only logical explanation I can give on this issue is that man, seeking to be something more than nature, is underestimating some of the wonderful abilities that nature has given us. Fortunately, for us, we still have these abilities; we just need to trust them a little more.

6.2 The Human-Computer Design

After spending almost a year looking for an apartment and, constantly talking about our possibilities and desires, Ola and I had more or less created the idea of what our future home should be like. The land property that was being considered was reawakening once again the hope that we would be able to build a house without making painful compromises for us. Conditions that we did not want to compromise on included: we did not want to get deeply into debt with the bank, we did not want to have less than three rooms, we wanted above-average construction quality, we did not want microscopic interior spaces, we wanted parking spaces and, of course, a house in an area close to our jobs and in an area that was quiet, without scandalous traffic, but at the same time not too far from the center of Tirana. Ola had an additional condition: whatever property we bought, it had to be one that we could sell for a higher price than we paid for it. That way, even if we did not live in Tirana in the future, at least if we sold it, we would make a profit. This meant that timber construction and concrete or clay masonry were not a good option, since the value of buildings with these materials in real estate in Albania is much lower than buildings with reinforced concrete structures. We chose the simple structure with a right-angled beam-column frame system because we were already traumatized enough by apartment designs with narrow room shapes, and we did not want to give ourselves the same headache that the idea of furnishing those spaces caused us. I am telling you all this to show you once again how dependent on social aspects are the choices we make for structural design. One day, talking about the house and, looking at the possibilities for using the land, based on Albanian normative, I don't know which of us came up with the brilliant idea: what if we built two houses, one for us and the other for our close friends, who, fortunately for us, had started living together and

were also looking to buy a house? We talked to them and we agreed. This would halve the costs of the land property, the costs of the project and the costs of applying to the municipality, but it would also mean—according to the regulations—that we would only be able to build two two-story villas with a total construction area of up to 80 m² each. Cost was one of the most important objectives for us and we decided that, as long as our initial demands were met, it was worth considering this possibility.

We decided to use part of the yard for parking. Even though the land property was already unusually small, we were okay with this fact and preferred to sacrifice a little space there rather than add another cost of excavation and retaining walls to the construction, which would be needed if we chose underground parking. Then, as for the foundations, the optimal solution was very simple, thanks to the flat terrain. The cheapest foundation for this case is the type with reinforced concrete isolated footings.

Now that I finally felt that we had given direction to the economic issues, the most interesting part came. “A rat-ta-ta-tat, instead of the boring rhythm one-two-one-two”. Personally, I really like the ornaments in the structure, but the university has trained us in such a way that we also have an appreciative eye for the material and functionality. Meanwhile, Ola does not have the same background and, like many people her age, she gravitates towards highly decorative styles of a bygone era. Here, a confrontation begins. I absolutely do not want my house to interfere with a time that it does not belong. It is one of my values as a designer. We have been taught that every work should show the time in which it was made and any variant that deviates from this principle will be treated as a bad imitation. The Baroque style, for example, is beautiful, but the works built in this style belong to another time, which means that they belong to a different building culture. Personally, I—and also most designers and builders of our generation—do not know the language of that structural ornamentation. Any attempt to restore styles from a bygone era on my part would produce a chaotic structural articulation. The elements risk appearing banal. However, Ola thinks otherwise, because for her, such forms do not imply bad ethics at all, since she is not inside the jurisdiction of structural design. Ironically, in a sense, she is a better structural designer than I am, because she is unbiased from professional calamities that the “ethics=form” paradigm caused. Furthermore, I do not want to interfere with someone's taste, much less someone I care. After all, design is not about measuring tastes, but about coming to the aid of people. In this respect, it is no small feat to fulfill the dream of having a house as your loved one has always wanted. I know that Mies van Der Rohe, for example, would have ignored without thinking twice the wishes of his clients or loved ones if they conflicted with his design vision. Despite the fame and importance that House Beautiful had for the discipline of architecture, his client, Edith Farnsworth, who lived there, said that the house was uninhabitable. She implies: “The truth is that in this house with its four walls of glass I feel like a prowling animal, always on the alert. I am always restless. Even in the evening. I feel like a sentinel on guard day and night.” [144]

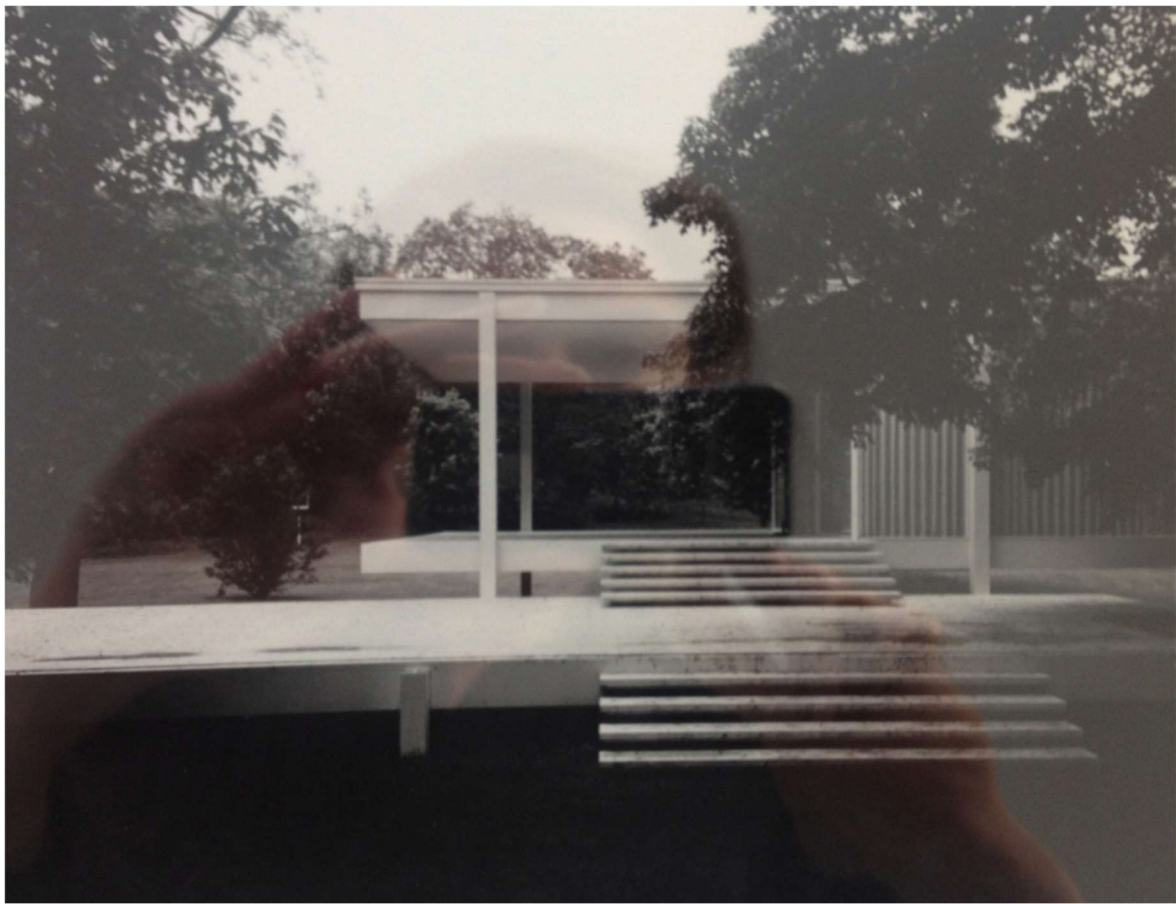


Figure 79 - House Beautiful, Nora Wendl, Geo. H. Steur, elevation, 1950, 2013, chromogenic print, (adapted from Wendl, 2014, p. 2).

For me, the values of others are not only important, but they are the main condition for my project to exist. Mies van Der Rohe could be considered a God of Architecture in his time because his design actions automatically became design norms. However, I do not have this luxury. I have to negotiate for every value, if I want them to be implemented in the structure. Moreover, the total denial of the values of the clients and the values of others is the biggest obstacle you can put in the dialogue with the client.

Nevertheless, to confirm whether Farnsworth's thoughts about glass walls were entirely individual or were actually based on the existential need for privacy and comfort, I showed House Beautiful to Ola and asked her what she would think if we built our house that way. Her first reaction was that it seemed strange and made-up. Her second reaction was that she did not want a house with a steel structure (there is a stigma among ordinary people that steel structures are more delicate than concrete ones). Then when I asked her about the glass facade in the rooms, she said: "Come on...in the little space we have there you won't know where to put the furniture, you say you want to fill the entire wall with glass." Which made sense but it did not come into my mind, since I was more worried about the privacy. I feel this method of design, where the building is produced by dense conversations between me—the designer—and the client—in this case Ola—is helping me grow as a professional as well.

By releasing contingency and by questioning everything during this stage you actually learn to become human again and learn to understand the structural design through the lenses of human culture.

Meanwhile, our friends, for whom I have undertaken to build a house, are less expressive of their desires and this is not a good thing at all. On the contrary, this is precisely the moment when I should try harder to understand what values they want their house to have. One initial value that we all agreed on while discussing about the project is privacy. We decided that both parties must have privacy, regardless and precisely because of the fact that our houses will be so close. Therefore, the closest walls between the two buildings will be without openings—just with small windows for the bathroom, for ventilation. Yet, I do not know how, but somewhere in the project, I would like to put details that bring these buildings together. Maybe it could be a shared terrace with a barbecue, or maybe a shared space in the yard or maybe just some visual articulations. I would like these small articulations to show our friendship and I would like someone who would pass by in the future to understand in some way that these buildings were built at the same time, with the same vision. Nevertheless, I would absolutely not like the houses to resemble apartments. I would like them to have their own personality. This way, if one of us would want to transform it in the future or even sell their house, it would not be deprived of its original form.

Since the land property was a bit small, we had to check the minimum conditions allowed by the legislation. However, next to us, there was a three-story building very close to the plot, which, based on the distances allowed between two buildings according to Albanian regulations, compromised the entire project idea (fig.80).

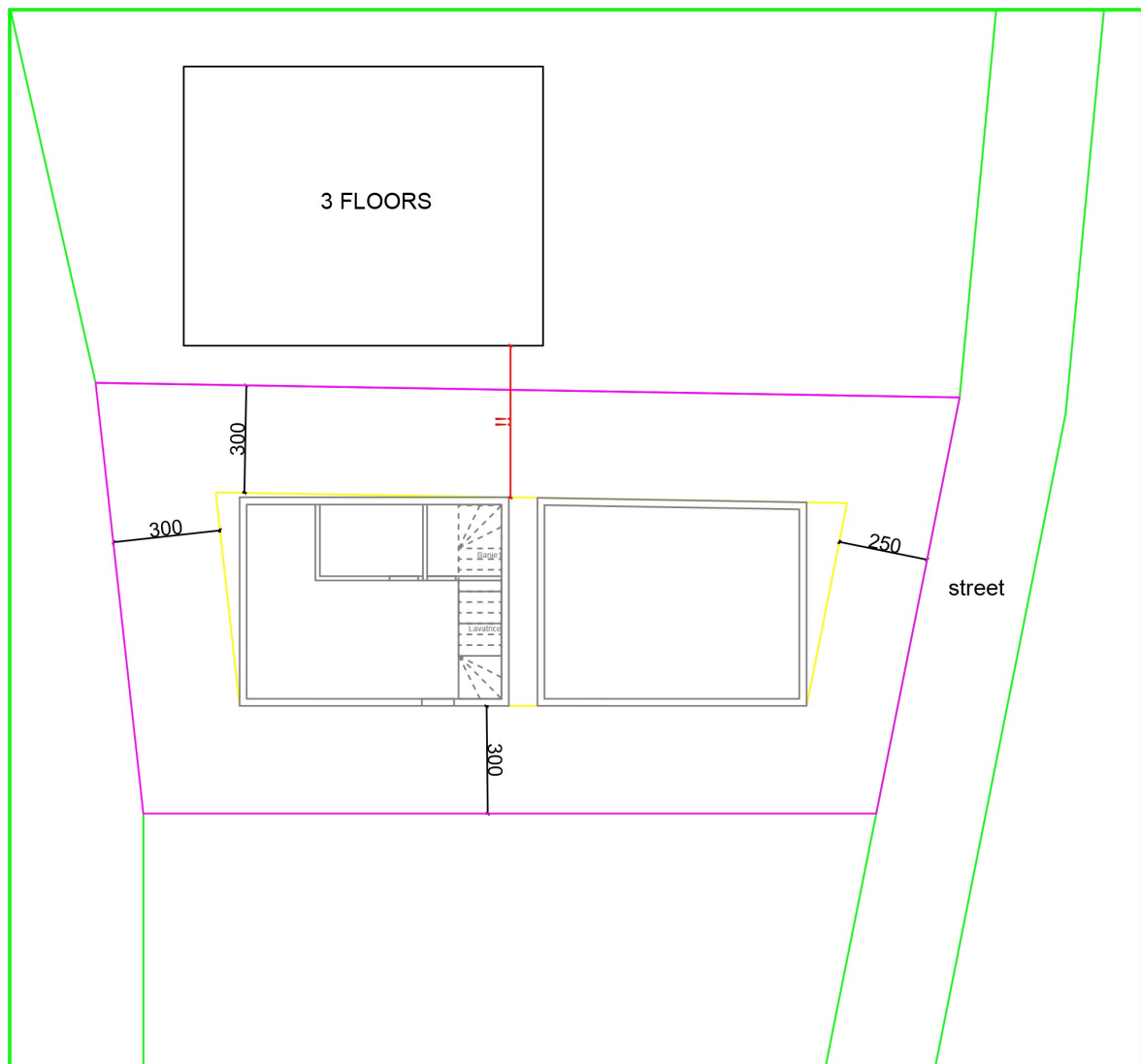


Figure 80 - Allowable distances from other land properties and the street according to Albanian normative and the proposed ground floors

Fortunately, for me, I found a contact at the Municipality of Tirana to ask if there was any possibility of building the structure while complying with the laws of the country. It turned out that, since the building next to us had received a Legalization Permit, not a Construction Permit, we did not have to respect the distance from it, but we still had to keep a distance from the adjacent plots and respect all other regulatory requirements. This were super good news because it meant that the initial idea was not compromised. The legislation excluded the condition of maintaining the distance between our house and the building in question, despite the fact that the building had a certificate of ownership. The reason for this is that the building in question was built without a Construction Permit at the time, and later, because of another law in Albania—that of the Property Legalization Law—the building was legitimized with a certificate of ownership. However, the fact that the law specifies “that distances must be respected with buildings that have a Building Permit” [145] eliminates the need to respect the distances with buildings that do not have one. I am sure that the Building Permit Law does not consider at all the fact that many buildings in Albania were legalized

without a permit. Construction regulations do not want to be associated in any way with the legal basis that deals with the legalization of properties without a permit. Taking them into consideration means taking into account the contingency and accepting the fact that construction can deviate from the norm. The horror of this act can never be accepted by legal construction initiatives. But the fact that it is ignoring the law on the legalization of buildings, creates a gap for the regulation resolving building permits, which is giving me the opportunity to build the home I have always wanted. If the phrase “building permit” were to be replaced by “certification of ownership”, for example, I wouldn't be able to build my home.

As soon as the architect at the Municipality confirmed this reasoning to me, I wrote to the landowner and accepted his offer to buy the property.

However, a week later he wrote to me and told me that he had changed his mind about selling the property. On the other hand, our friends had a family problem: one of their family members was diagnosed with a serious illness. Thus, they could not take any further steps nor consider spending money to build a house, at least not until things got better.

Usually a “no” to me means there is still potential to explore. Indeed, according to Chris Voss, who is a former FBI hostage negotiator, a “no” is actually the start of negotiations. [146]

Regarding negotiations, my principle as a structural designer is that people want to be understood and accepted. Listening is actually the best way to achieve this. By listening carefully, I hoped that the landowner would feel more valued and would express and clarify his opinion and feelings openly. At this stage, the design becomes completely part of the realm of feelings. Negotiating the project means playing the emotional game on which human society was created. The owner of the land is not a man of few words and that is a good thing. All the conversations we had, lasted at least an hour and included absurd things. Sometimes I had to talk to his friends and listen to their suggestions, sometimes we talked about raki and wine and culture in Iran. Ola often lost her patience while listening to me speak because, for her, negotiations are an objective activity: someone accepts or not your offer. Indeed, many people approach a negotiation so busy with arguments to support their side that they fail to listen carefully to others. When we radiate warmth and acceptance, conversations flow naturally. When we create a conversation with a level of comfort and enthusiasm, we attract people around us and they are more inclined to accept our offers.

A method I like to use is to give space to the other party to speak and fill the silence. I do not rush to fill the silence. On the contrary. I kept my mouth shut while he explained me the reasons for this change of heart. The dynamics of property real estate prices in Tirana are moving at an extraordinary pace (two-three times in two years and the trend is growing), which had scared the owner that with the offered price he would not be able to buy another property in Tirana. The owner lives abroad, but, as he says, he would like to spend his

retirement in his homeland and would like to have a house, even a small 1+1 apartment in Tirana. The price we first agreed on for the land was not enough to buy an apartment in Tirana.

Before discussing again with the landowner, I thought about finding “The Black Swan”, which I could use to negotiate the price and build my villa. “Black Swans” are leverages you have to think about before starting a process of negotiation. This theory comes from risk analyst Nassim Nicholas Taleb. [147] He invites us to include contingency in the negotiation process. The idea is to do your homework for the information you already have (such as the other person's name or knowledge about him and the property etc.), and to be aware that there are things that exist and are essential for negotiations, but you still don't know. Lastly, to be aware that there will always be things that we will never know that will directly affect the negotiation process—for example, the investor may get sick and the negotiation process may be interrupted. Indeed, I noted all the information I had, and tried to reflect. Let's not forget that the owner wanted a house, however small, to buy in Tirana. The next proposal I made to him was that we could build two villas—one for me, one for him—as long as he offered me the land property for free and I built him a one-story apartment at my own expense. However, he demanded that his structure be treated the same as mine. Therefore, if I were going to build a one-story structure, I would build him a one-story structure. If I were going to build a two-story structure, his structure would have to be the same. The reason was entirely social; he did not want his building look inferior than mine.

Of course, the fact that the negotiations were being conducted over the phone was a problem in itself, but even in this case there is an opportunity to make the conversation warmer. Tone of voice, for example, is very important. Forget the authoritative voice. Speaking with authority during negotiations is like scoring an own goal. You are sending signals of dominance to the other party, who will either react aggressively, or spend energy to oppose the attempts to be controlled. That is why I was also using a positive, playful tone, which showed a sense of empathy. The key to doing this is to be relaxed and smile as you speak. A smile, even during a phone conversation, has an impact on the tone of voice that the other person would feel. The beauty of empathy is that it does not require you to agree with the ideas of the other party (in this case, the claim that the villas were the same height was absurd to me, for example). However, seeing the situation from the other person's point of view, you immediately give him a message that you are really listening.

Negotiations continued. One tool that I always like to use during negotiations with clients is to use “calibrated questions”. Such questions were “How am I supposed to do this?”, “What does this project look like to you?”, “What is your objective?”, and “What type of material do you like to make the structure so that you can afford it with the budget you have”? Another tool is to make sure that the other party sees that he has something to lose if he does not act. In his case, it was the fact that he was getting old and, for almost a decade, he did not have

the opportunity to make something out of his property. In addition, the fact that I am a structural designer is important to him, because I will follow the construction works of his building, which he cannot follow since he is in another continent. Third, I always make sure not to put him under pressure and give the other party time to reflect. This is difficult to do if you are wearing the mantle of a negotiator. I learned all three of these methods in the book *Never Split the Difference* by Chris Voss. [146] If Chris Voss, who negotiated hostage situations, says that insufficient time is often an illusion even in a kidnapping case, then surely the deadlines we set in our minds for completing a construction deal are also more flexible than we think. After negotiations with the landowner, we agreed that, as long as the total costs for both villas and the land were divided in half, we could make both structures the same. Therefore, we agreed that I would build two villas and the landowner would add a portion of the money for the construction of his villa.

This changed everything regarding the project. It meant that I would build a house for myself and an adjacent house for someone I did not know.

Regarding our home, Ola and I drew our ideas on a floor plan in AutoCAD. At first, I drew the layout of the floors. Then I planned a strategy for the stairs. My goal was to save some space and I planted the stairs in such a way that they fit perfectly with the layout. Afterwards I suggested that the entire ground floor had one bathroom and the rest of the space would be the living room and the kitchen. However, Ola suggested otherwise; and, as she was speaking about her ideas, I was carefully moving the mouse and drawing the sketches. We explored the possibility of having a small room/studio on the ground floor. Usually, she is not like this. Usually I am the one who tries to “optimize” everything by “using” the space at maximum capacities and she is the one always wanting for spacious areas. I feel that this feeling of attunement is doing us good as a couple and is also improving the project-idea of a home. And indeed, we were able to organize a studio, a bath, a kitchen, and a living room in the ground floor by doing some diagrams explorations. Whenever we run out of ideas, I would find something to busts things up, like drawing a symbolic representation of a furniture in order to understand the space better. These elements worked like heuristics, helping the design process flow. For the first floor, I suggested to divide the space in half by the largest direction, to have two rooms and one bathroom. In this way, it would make the rooms resemble squares more than rectangles. I made some symbols for the beds and other equipment in order to understand the space better. We found out that, although at first sight, the squared rooms would have been easier to decorate, this was not true in our case. On the contrary, after we tried to divide the spaces differently by halving the shortest span, the assignment of rooms became much easier and the spaces appeared more spacious. Next, you can find the schematic version of the division of spaces that Ola and I made (fig.81).

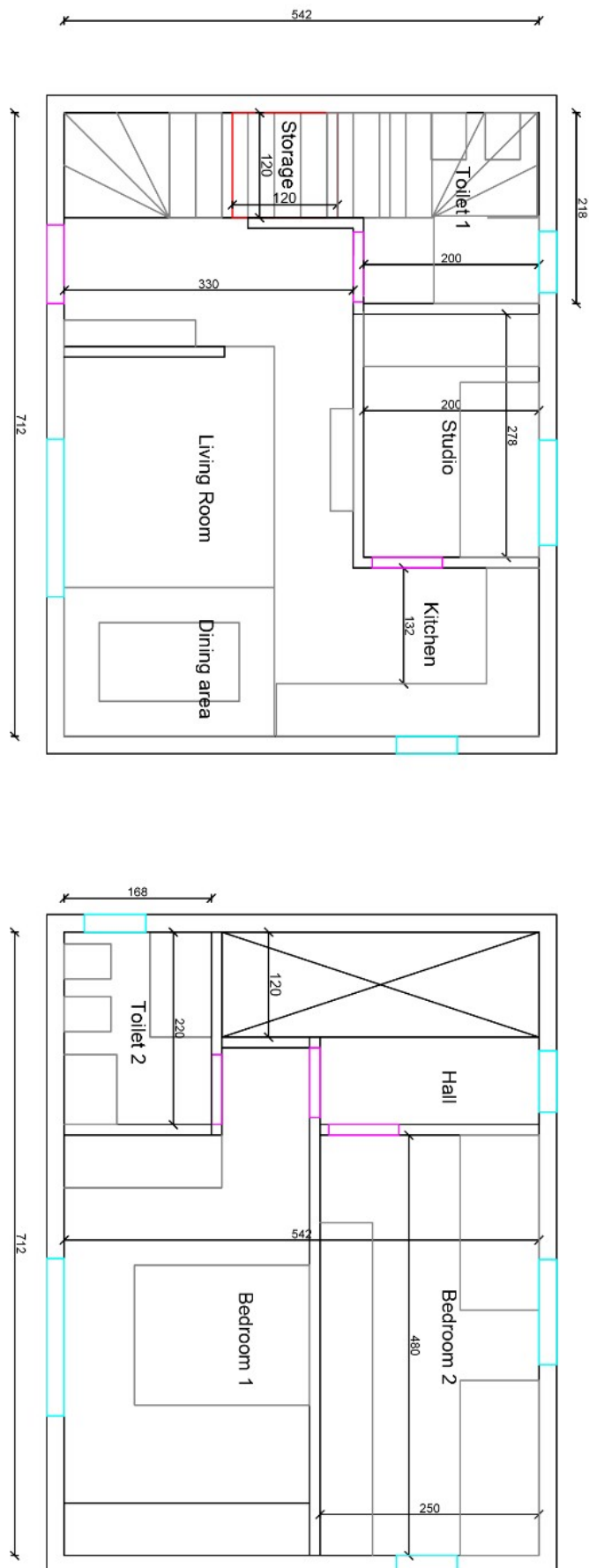


Figure 81 - The first sketches of our home

As for the structure, I was between two variants of columns placement. The first choice was a structure with columns only at its corners.

The second was a structure with columns closer to each other, using the footing connecting beams as both-end objects; connecting the isolated footings while also serving as footings for a part of the walls (fig.82).

It was not necessary to check for options with more than four columns because it would add more footings, and it would increase the cost of excavations and the cost of concrete, which would result in an expensive structure. The cheapest variant regarding to the models and regarding the cost estimation was the one with four columns per building and isolated footings beneath them, which uses foundation beams as both-end elements.

According to the computer analysis, I found that in the case of this building, it was more cost-effective to save concrete rather than steel.

For the typology of the slab, I also had it very simple; thanks to a script that I had designed for this problem. Considering the possible spans for our villa, the most practical slab (because it could easily insert the hydraulic installations), which at the same time had a much cheaper cost than the others for the same load-bearing capacity requirement, was the one-way ribbed slab (fig.83).

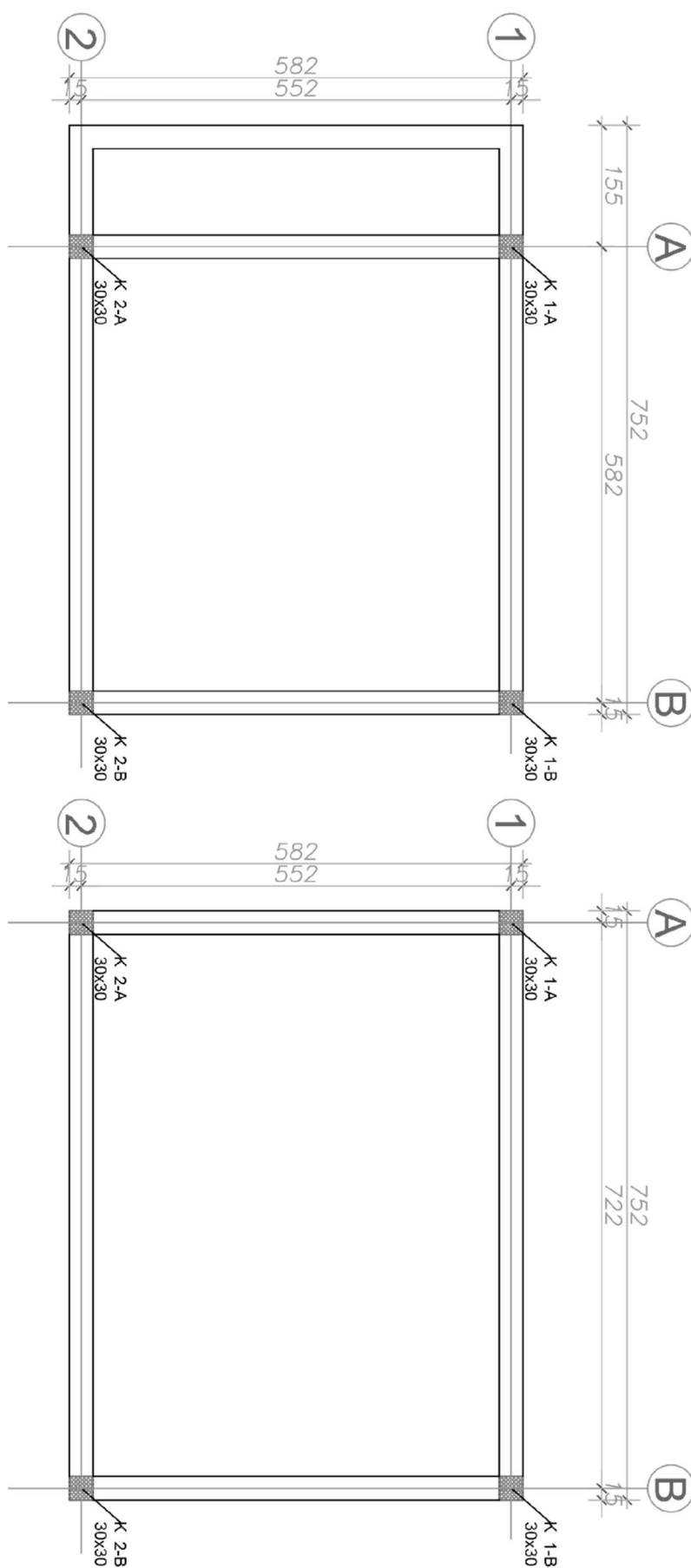


Figure 82 - Column positioning. Final variants

Technical drawing of a rectangular reinforced concrete slab (Tr. 5 A/1-2) with dimensions and reinforcement details.

Dimensions:

- Overall width: 582
- Overall height: 752
- Clear width: 552
- Clear height: 582
- Top reinforcement bar spacing: 40, 40, 40, 40, 40, 40, 40, 40, 40, 30
- Bottom reinforcement bar spacing: 12, 12, 12, 12, 12, 12, 12, 12, 12, 12

Reinforcement Details:

- Top Reinforcement (Tr. 4 A/1-2 (30x50)):** Shaded area indicating reinforcement.
- Bottom Reinforcement (Tr. 6 B/1-2 (30x50)):** Shaded area indicating reinforcement.
- Left Side Reinforcement (Tr. 3 1/A-B (30x50)):** Shaded area indicating reinforcement.
- Right Side Reinforcement (Tr. 3 1/A-B (30x50)):** Shaded area indicating reinforcement.
- Top Left Corner Reinforcement (Tr. 7 (50x30)):** Shaded area indicating reinforcement.
- Bottom Left Corner Reinforcement (Tr. 2/A-B (30x50)):** Shaded area indicating reinforcement.
- Top Right Corner Reinforcement (K1 1-A 30x30):** Reinforcement bar at the top right corner.
- Bottom Right Corner Reinforcement (K1 1-B 30x30):** Reinforcement bar at the bottom right corner.
- Top Left Corner Reinforcement (K1 2-A 30x30):** Reinforcement bar at the top left corner.
- Bottom Left Corner Reinforcement (K1 2-B 30x30):** Reinforcement bar at the bottom left corner.

[illegible]

Figure 83 - The chosen structural design plans of the first building

The chosen variant for the structural design projects is shown in Figure 83. The general rules for determining typologies would fail us in this case, as they would suggest two-way slabs, since the shape of the floor plan resembled more a square than a rectangle. However, thanks to the rapid evaluation of all cases by the computer, using the algorithm I made for this particular problem, I managed to find a cost efficient typology even at this stage (according to the algorithms, by choosing the one-way ribbed slab typology, I would manage to save 395011 lek, compared with the suggested typology from design codes⁸).

As for the structure of the landowner's house, I had to negotiate again, since his next request was not to spend any money on his building, as he was going through a difficult period economically. We agreed that I would do a smaller two-floor building for him, where I would cover all construction expenses. Ironically, this was actually one of my earlier suggestions, which the landowner had rejected. The fact that he was coming and suggesting this to me shows once again how important it is to enter negotiations with a positive approach. Do not be afraid that other people sometimes refuse your offers. There will come a moment when they will look for a solution themselves and most likely, it will be one of the solutions you have offered before.

However, in order for the offer to be possible, I had to design a cheaper structure for his villa than I have already considered. The owner of the land does not have the same desire to necessarily have a reinforced concrete structure. For this reason, I had to do some tests to explore other forms of structures with other materials and conditions. One idea was to make a one-story apartment with a wooden truss and an attic above. Another idea was to explore a different shape and materials and keep the reinforced concrete frame system. Another was to make the structure with masonry with pillars at the corners. Of the three variants, the most economical form resulted in the one with a reinforced concrete frame structure with the shape of the structure shown below (fig.84).

⁸You can find an example of outputs and the scripts parameters about slab typologies at Appendix.

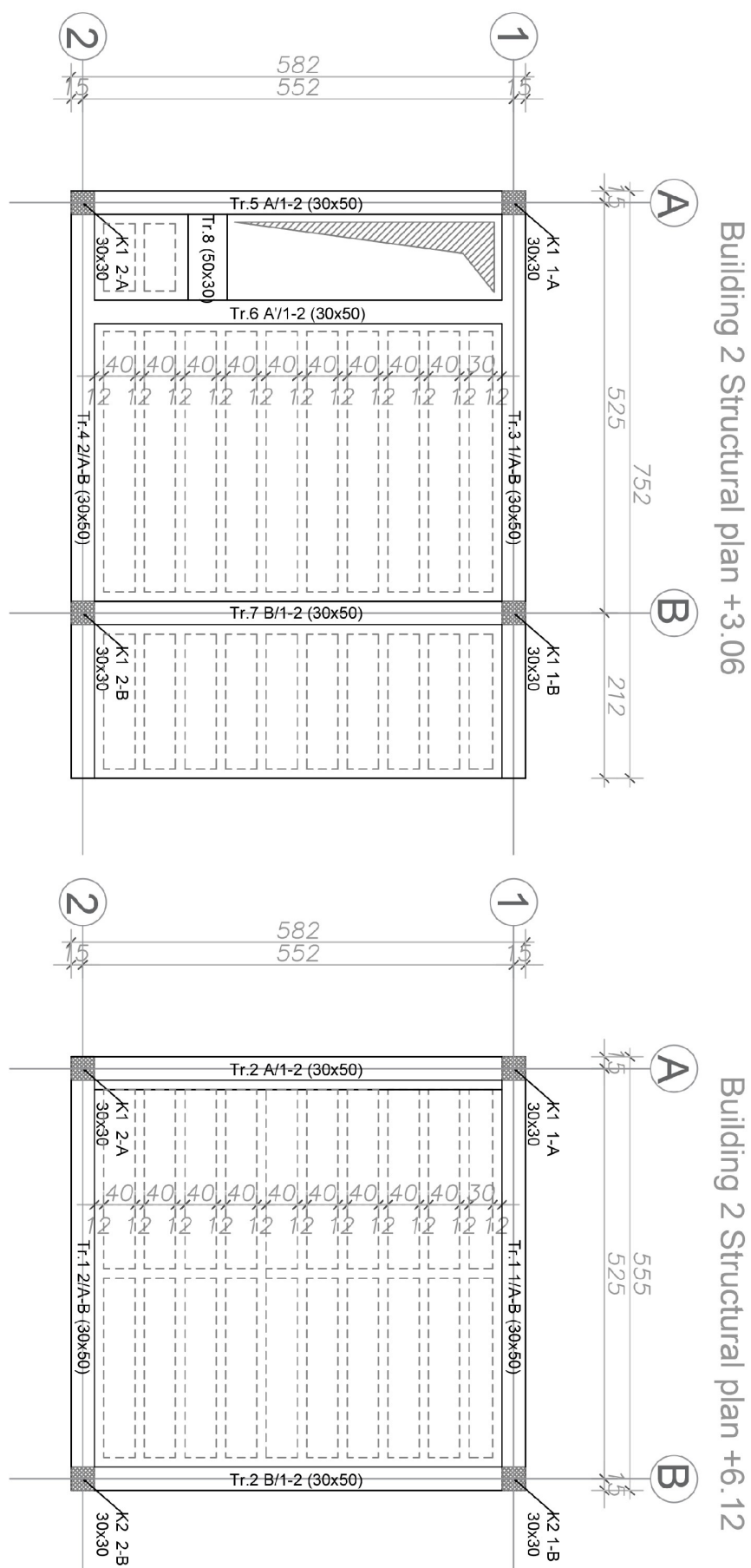


Figure 84 - The chosen structural design plans for the second building

6.3 Findings and Discussions

If the ontology of structures as a conglomerate of discrete finite elements is true, than in order for it to gradually built up the full reality inside the simulation, it has to be re-presented as a large data structure comprised of facts plus rules for relating and applying those facts. However, just by analyzing the above case, it is very difficult to formulate, let alone formalize, the theory required for structural design. It is not simply a problem of cataloging ten million facts about how to connect ten million finite elements.

To exhibit genuine intelligent behavior, a vast store of knowledge is needed—something humans usually take for granted but that must be spoon-fed to a computer⁹. This is not the sort of knowledge that is in any “*Theory of Structures*” books. In stark contrast, structural designers first rely on the everyday background of understanding that helps them make sense of events in the world. In the previous case, this shared, ordinary understanding includes everything from “The landowner has money” to “The landowner’s decisions are influenced by his friends” to “When the land owner is in Iran, his left foot is also in Iran.”

In fact, it is a big problem to make a database that can understand simple design tasks, since such an understanding requires vast background knowledge. To understand what I am referring to, read a part of the process Ola was doing during the design of our home:

“Ola saw a wardrobe in the room. She modelled it.”

Ask yourself if “it” applies to the wardrobe or the room. Ask yourself the same question but this time I add the fact that “She wanted that space full of light”.

Notice how when we answer questions we try to imagine ourselves in that situation rather than examining formal knowledge about those objects. Understanding what is being described requires human skills in how we move or orient ourselves in space, or how light enters and its importance to us in certain situations. Skills like these, which would normally be ignored in a simplified model in simulation, turned out to be essential for making sense of ordinary language. Our ability to imagine experiences helps us determine what information is important and how information is related to one another. In the same way we interpret information that has to do with orientation, such as “close by” or “over there”. The correct interpretation of these is related to embodied orientation, which is a strong assumption that the meaning of language is rooted in physical experience.

A third problem—related to the other two—is that there is no limit to the number of important features in structural design. In other words, no one can determine exactly which features are potentially relevant, nor can we collect statistics for each of them. However, if

⁹ It is the same conclusion that Douglas Lenat arrived in his book “*Computer Software for Intelligent Systems*”. [149]

we start with a set of important features and build software based on them, it is very difficult and sometimes impossible to add new features if later, the selected set, turns out to be insufficient to adapt to the transition of situations.

To make something out of this, I have to limit the design possibilities artificially, but, as you may have understood by now, the notion of structural design is not an activity with well-defined limits, but rather involves a series of variables that link it to other human activities. By formalizing and limiting the possibilities, the possibility of deviations from the norm is not taken into account.

Consequently, the program that uses these scripts cannot be said to understand dealing with structural design at all. This can be easily seen during the case study above by showing situations that deviate from the norm. How does the computer transform the project regarding the fact that, unlike what was originally thought, instead of two villas for two friends, it will design two villas for two strangers? Or with the fact that, instead of two identical villas, it will make two villas with different structures to meet the requirements of both parties that are constantly changing? Intoxicated by the digital spirit, one would certainly answer that he could solve this problem by including these events in his later scripts. However, there will always be abnormal events of daily activities that may occur and cannot be taken into account: heavy machinery may be very noisy and the neighbor may complain, there may be too many people inside the structure jumping at the same time, etc. This contingent manner of handling atypical situations becomes clearer when additional questions are posed, to see that the program does not understand the structural designing events in the same way that structural designers in our culture do.

Furthermore, it is difficult to imagine that a script that includes features within the domain of the profession would identify the full features of structural design without including other scripts outside the domain, but still closely related to structural design, such as, for example, meeting a client, imagining a home, negotiating with stakeholders, getting construction permits, setting structural values, understanding non-professional values, doing an inspection, interpreting laws, arguing with you wife, taking notes, speaking about raki with the landowner, looking tectonic articulations, improving relationships, etc., etc., which might lead one to deal with a structural design without intending to analyze a structure. It would be more acceptable for someone to use a software knowing that its responses will be limited and to continue to obtain solutions from it until his expectations are not met and then to rely on his experience. Normally, when we imagine a construction event, we do not assume that a person dealing with a structural project will not intend to design a structure. Therefore, this hypothesis fits well with our professional understanding. However, the current attempt in this second case, which seeks to make an intelligent program that interpret structures for us, leaves us completely unprepared to answer the problem of how to choose the right script.

To achieve a product using the topological approach, I have to treat every situation on the computer, each with its prototypical description and an objective. Then I have to give descriptions for the objectives to identify the situations in order to determine their domain. Then I would have to give descriptions about their domains. But where would such a regress stop? Structural designers, of course, do not have this problem. In Heidegger's words, they are already in a situation, which they constantly revise. [86]

Working with scripts, exploring and making decisions from these explorations can be useful, as was shown in the case study above. For example, exploring the results of the cost of construction items for the structure of the villa, I discovered that saving concrete—especially in the case of slabs—is much more important than saving the amount of steel. I discovered this specifically by playing with the parameters and noting that the first choice for the algorithm as the most efficient slab in terms of construction cost was, strangely enough, a monolithic slab with a thickness of 12 cm with $\phi 18/15$ cm reinforcement. Of course, I did not choose this typology because, for a span of about 6.3 m, that our structural project has, such a slab would not have sufficient stiffness and would vibrate, despite the fact that it would meet the condition of bearing capacity. However, these numbers made me explore further and I noticed that, at least for my villa, the pattern was very clear: if you save on the volume of concrete, you will achieve a structure with a relatively satisfactory cost. New programs, such as the topological solvers combined with neural networks, instead of normalizing patterns, would rely on powerful operators to select discriminating traits, but would still be sensitive to distortion and noise. In the case when Ola and I did the structural design, noise was not tested and then excluded, but in fact, it was simply ignored as unimportant. We did not, for example, calculate all possible structural shapes and then extract the most cost-efficient shape. Instead, we started with a specific form, which was the reinforced concrete frame, knowing well from our culture that these forms would bring a lower overall construction cost than, say, for example, the reinforced concrete shells. Here again, we note the experienced designers ability to distinguish the essential from the inessential.

I have shown above the importance of the human ability to distinguish the whole and to ignore the unimportant things during the design. It is important to me that the computer gives the structure at the cheapest possible cost. However, by this, as I explained before, I do not really mean the lowest number of money in lek—or any other currency—from all possible variants in the design space. Because there are variants that we, as humans, ignore without considering them at all, thanks to our ability to adapt to the culture and situations in which we find ourselves. Since we take many things for granted—for example, that floors must be horizontal—it is by no means clear what the pronouncement “a complete description must take the form of a set of instructions” means.

Consider, for example, the instructions we would have to give a computer to select a rectangular column section from a given set of different section configurations. If we were to try to turn this behavior into a set of steps, as Patrik Schumacher suggests, we would develop the script in this way:

“Pay attention to the guidance offered, look carefully at the available structural sections, observe their shapes, then decide.”

However, such guidance is not an algorithm and would have to be more specific in order for the computer to cope with it. How would the computer be able to distinguish a rectangular section from a circular section? One could propose a simple rule such as counting the edges and, as long as the result is four, the program would refer to that section as rectangular. But this question simply opens the way to an endless set of recursive questions. What property does an “edge” have in practice, that people recognize it as such and, consequently, we should give it as an instruction to the computer to recognize it too? If we decide to program the computer to determine the edges by taking the points of a structure and joining them and the smallest distance between them gives the edge, we are again left confused in determining where these points that we will tell the computer to examine come from. Someone could say that even humans perceive objects unconsciously starting from their points. But do we? And why do the questions end precisely here and not, for example, at the atoms or molecules of the material of an object? And if the instructions for this simple task are not enough, what instructions would you give a software to determine aesthetic values without having the aura of structures inside simulation?

In a sense, the behavior of a structural designer certainly has typical rules. For example, I like to have a checklist as a guide before negotiating with clients. However, the claim that the rules that organize the design process can be produced by a computer or by some equivalent formalism is another thing. This belief that any form of design activity can be formalized in terms that can be produced by a computer leads much topological approach to take for granted that design can be represented by a set of input-output correlations. However, as we have seen before, it is not clear even to us humans what can be the outputs and inputs that we are supposed to have. How do I predict that the owner prefers a certain villa model because his friend saw it on Pinterest and then, after a long conversation where he feels he has gained my trust, he decides to accept that my proposal makes more sense? Then, if the design requirements extend over years, the influence of social aspects becomes larger. Indeed, the design seven years ago, when I first spoke with the landowner, had completely different conditions compared to the current structural design. Moreover, our requirements are very different, which means that the structural design values are very different. Since computers have a hard time positioning themselves in situations where we find ourselves and have an even harder time adapting products when we change values as individuals and furthermore as a society—in other words, in the language of computing,

when we change the inputs and outputs—then this premise falls apart. This leads to a single conclusion: Programmed behavior is either arbitrary or rule-bound.

In our lives we are in fact situated in “sub-worlds” such as the world of architecture, structural design, mathematics, etc., but each of them is a way of sharing out the everyday world. That is to say, that the sub-worlds are not connected to each other as isolated physical systems that form the whole, but are in fact local elaborations of the Whole, which they presuppose. If the first approach were true, then we would not understand the world at all because the everyday world would be involved only in the union of its parts. For example, even if you were a good structural designer, you would need to master all the other fields in order to be a human. However, this is not true. There is no way that the everyday world can be produced just by combining sub-worlds either. Consequently, we cannot answer the question of what the world really is.

Programs without a complete understanding of the world—such as the ones that use FEA—are engineering feats, but they are not steps towards truly intelligent systems, and consequently are not promising contributions to creative generative design.

Topological approach presumes these sub-worlds enable the computer to contain the structural values. Like FEA’s sub-worlds, Schumacher believes that structural designers can start their design with a well-defined situation within a domain that represents the science of structures, which is described by measurable characteristics. By making this assumption, Schumacher believes that he can use this domain to explain all the problems and characteristics of structures in real life. However, these features, which represent a stereotyped domain of structural design, make sense only when the context is interpreted only according to a specific discourse. This independent domain, which seeks to explain real life, begins to show its shortcomings when one compares or confronts it with activities in everyday life. For example, does the model made with FEA represent the structure in reality? It is clear that the answer depends on the situation in which the structure is placed. There are certain situations when the model and the structure are one. Structural designers can use Etabs—or any software that uses FEA—to roughly analyze the mechanical behavior of the structure. There is nothing wrong in principle if they want to analyze the behavior of structures in reality using computer models, as we do with FEA software, when we capture a simplified version of typical elements in construction, as long as we are aware that what we are doing does not represent the full reality. However, Schumacher assumes that he can use these methods to explain the values of real structures, which means that, according to him, the structural design sub-world discourse can be treated as if it were a complete isolated world. As we have seen, the real world of structures is far more complex. Questions that software need to understand before their simulations being treated as part of the world might be: “When the client came at the meeting did he wear clothes? Did he walk forward or backward? Did the designer take notes with his hand or with his ear?” If the program

answers, “I don't know”, or worse “Error404” we feel as if all its answers so far have been coincidental. The point in this case—and in all the cases I already mentioned—is not that there are specific things that structural designers can do or perceive and computer programs can't. The point is that in each case there are answers that we take for granted as simple, but that software cannot perceive at all. As we saw in the case study above, these answers affect directly the structural design process.

One thing that contemporary designers got right is that the modern project is constantly seeking complex forms. Indeed, today's culture is unable to go back and accept the values of a previous time, but also to accept that the values of the present are inviolable. This has happened because the promise of this culture is monumental. It is to enlighten society. However, this promise that one day society will be enlightened by accepting, among other things, to change the perception of structural elements is excessive. It is not possible for the simple person to enter the discourse of structural design so deeply that he does not distinguish the structural elements of beams and columns, but perceives discrete computational elements as the final elements. If professional discourse changes and only accepts conceptual systems within their field—such as finite elements—then society will have to be asked to one day learn how to use a finite element analysis program. Since this is unlikely to happen, structural design will become even more distant from everyday life. As I have said before, when structural designers seek to distance their activity from the clutches of life, they in fact undertake projects that do not carry the values of life. Instead, for there to be a marriage between the activity of structural design and social life, designing professionals must embrace the ways of perceiving reality of ordinary people. Lines, surfaces, points, are nothing more than Gestalt abstractions, the way in which the common man perceives reality. That is why even pointlike elements, such as isolated footings, one-dimensional elements, such as beams and columns, as well as two-dimensional elements, such as slabs and walls, are so closely linked to the culture of construction. They initially represent reality, derived from a "purely human" mechanism, and only then, they are turned into mathematical concepts.

7. CONCLUSIONS AND FUTURE DIRECTIONS

Chapter 7

7.1 Epilogue

Following the idea of total order, structural designers are designing in a state of total denial of the power of the other of order. Whether structural designers are agents or victims of the “regime” is of little importance. What is important is that they are positioned within the current values of the modern project that seek to eliminate chaos. However, since chaos cannot be removed, their actions and theories should not be seen in isolation, only within their profession.

Structural design is exposed to contingency and this unclear mass does not enter into any of the computational design schemes. Not only structural design, but also the construction process together with the structures themselves are contingent. All fields have some kind of uncertainty, but contingency in structural design is particularly important for two reasons: (1) Structures are constantly affected by external factors, since they operate for a relatively long time and are closely related to the activities of daily life. (2) There is a tendency taken from previous cultures, also thanks to the close connection that this activity has had with calculations, that channels this activity as a completely scientific task (in the sense that it is completely regulated and calculable). The tendency of contingency is to levitate and increase its impact precisely in such activities, when it is required to regulate everything and completely suppress irregularities. As a result, contingency becomes in fact the greatest influencer in this activity and its zealous denial by designers only makes their activity vibrate outside of reality. Even the values that structural designers seek to achieve fall outside of reality and all this becomes a game of manipulating numbers and geometric shapes. The qualities of a structural designer to solve contingent problems are unfortunately neglected. Creativity, composition, synthesis, ethics, aesthetics etc. These qualities have an enigmatic peculiarity that gives the project values that distance it from tasks that can be undertaken entirely by computers. By accepting contingency, I am not lobbying for irregularity or indeterminacy. What I am proposing is that solutions for structures be situational and based on human experience, not simply on design manuals or computational methods. Science of structures deals with facts, but man, who is the source of facts and the user of the structures, is neither a fact, nor a set of facts. On the contrary, we are the ones who create these sets of facts during our encounters with the world. This world is perceived by us involving our sensory capacity. There is no reason to suppose that the same reality that we perceive can be perceived differently by any other means. Thus, science can partially explain experienced life, but it can in no way replace it. Experienced life does not always provide solutions to problems, but it is the only way we can rely on to move beyond assumed expectations when

manuals and regulations fail us. Nevertheless, the normatives are important, because structural design needs a hierarchy of values, otherwise tolerance will lead to the impossibility of having regulatory systems.

Contingency in design requires us to share our fates with others. It is precisely after practical experience that designers learn that they must listen more, collaborate more, and learn to negotiate. This model of the structural designer as an interpretive agent also comes as a result of the values of the spirit of the times and requires professionals to come down from the pedestal they have placed themselves on and interact with others. If we accept that social connections are part of the design process, then the structural designer has a special role to play in this reconfiguration: that of mediator.

Understanding structural design means having an eye for finding the socio-cultural values of the current cultural era. The zeitgeist is closely linked to the use of computers. With the increasing use of computational design tools and AI, they will offer the opportunity to explore more structural forms and achieve construction values while meeting the design requirements in terms of performance. These tools influence us and tend us to immerse in the world of simulation. However, the designer-computer relationship is not the only key point in our zeitgeist. Understanding today's culture is a bigger task than that. Culture is a process of repetition that includes patterns from all previous cultural periods. To find values in structural design, you have to dig back to past cultural experiences. The never-changing values for a designer are experience and the influence of the tools used. Both of these have their starting point in the realm of feelings. In fact, even seemingly “objective” objectives such as comfort, structural character or structural sincerity flirt with the realm of feelings. An important effect that structural designers do not want to take into account because it is beyond their control is the aura of structures. It is in fact the ability of structures with their authority to offer messages in human culture that lies at the core of structural aesthetics. The formalization of the ordinary loses references to the ordinary. Structures in reality, through their aura, propose new realities.

The problem—and the premise—of the modern project is that it requires society to be enlightened. Therefore, according to this claim, a day will come when it will no longer be necessary for values to be transformed and we will achieve perfection as a society. This claim makes the paradigm of the modern project stand and at the same time makes it impossible for us to return to previous values or to accept current values unchanged. However, in stark contrast with the modern project belief, no society can ever be perfect. It

cannot be an organism because it lacks automatic self-regulation and true harmony. Nor can it be a machine because it would be too rigid and idealized while life is complex and contradictory. This is where the value of creativity comes into play, which thanks to the modern project has become more important than ever. It is precisely creativity that allows us to put norms to the test, since to create is to break meaning.

The structural designer, as an agent of culture, needs abilities to negotiate as well as invite and accept the ideas of others. He needs computational skills to explore the potential of the computer as well as technical skills to design structures that satisfy the gravity's conditions. He must also attune to the environment and others. This activity is contingent, therefore the solutions can only be situational. The human touch brings the solution home, to our reality. Computational structural design seeks to make everything clear. However, the ambiguity that human communication offers is in fact the price we must pay for introducing new experiences and for allowing contingent agents to talk back to us.

Structural optimization offers hope as a methodology for structural design, as it is in touch with the spirit of the age. However, because solutions cannot be predetermined and today's society does not accept formalisms and rationality, but also because computer solutions do not represent the full reality, optimization methods and FEA cannot provide solutions for structures independent of human touch. Since structures and the surrounding environment are part of our being, in order to feel part of the environment, it is important to offer a design that carries the same design values that we believe society should have. Since it is impossible to put all the facts inside a computer, it is impossible to have a generative design that represents life. The reason why this problem does not affect people is that they are already situated in the world.

Programs that use FEA and optimization methods are engineering achievements, but they do not convey a complete understanding of the world. Consequently, they are not promising contributions to fully generative design that carries structural value. To achieve this, computers must deal with the emotions, desires, and interpretations that people make of the concept of "being a human", which leaves people open to the infinite possibilities of human life. If the themes that organize our lives turn out to be unprogrammable, then the so-called optimization methods and the topological approach of interpreting reality are not supposed to do what they claim to do.

The improvement of computing power has radically transformed structural design, expanding the methodologies for form synthesis and structural analysis. It is precisely the inability of humans to decipher “fluid” structural forms in the same way that computers do that is both the supporting argument and the main flaw of the idea that structures are composed of “finite elements”. The fact that computers cannot distinguish structural elements such as beams or columns has led designers to believe that these concepts are formalisms that can be improved. However, columns, beams, etc. are “Gestalt abstractions”; how humans decipher reality. FEA is a design method based on mathematical discrete elements. Since these discrete elements cannot create the whole, they are unable to produce structures without losing their expressive power. The problem of confusing methods with means, i.e. the “How-s” with the “What-s”, have often encountered in our culture and it is happening again now that FEA is used to give meaning to structures. Instead of deciphering reality themselves, structural designers bypass this process and use FEA instead. However, this way of representing reality has its limits compared with our capacity of understanding reality. There comes a point in structural design when humans have to decipher forms using human senses. The topological forms that Schumacher and other contemporary designers refer to, that are created by the improvement of science, are in fact trends in cultural aspects that are seeking to increase the degree of complexity of structures. Of course, the methods that we use also make this possible, but this does not mean that these methods have brought about this change. It is the cultural aspects of our era that are constantly seeking complex structures, which has led to the suggestion of the ontology of structures as topological conglomerations of finite elements, and not the capabilities of these methods themselves.

As we have seen, it is not the computers that decide during generative structural design projects, but structural designers themselves. To speak of computer heuristics in these cases is misleading, since no one has managed to formulate the rules that guide the preliminary choice of structural form during the pre-design stage, or even to show that at this stage, when insight is required, people follow rules. As a result, we are left without a computational theory for the essential first step in all problem solving, which is to distinguish essential from inessential.

To a certain extent, structural optimization does give hope as a methodology for structural design because it is in touch with the spirit of the age. However, as already mentioned in Chapter 2, structures themselves are contingent so any solution that is pre-determined is irrelevant. In addition, as mentioned in Chapter 3, the present society has shown that it does not accept rationality and formalism anymore. Not only that, but in Chapter 4 we saw that

mathematics in itself, computational in itself, and solutions generated only by computer processes cannot solely solve human problems. Since all three of these problems are present in computer optimization, solutions cannot come only by using optimization methods.

Which means that the main concern of man is not to achieve any specific objective at the end of his life, but these objectives become important during his life through his experience in the world (and of course they are dynamic and can change depending on experience). Whereas computer objectives, on the other hand, have an arbitrary relationship with values outside the computer and therefore must be explicitly defined at certain moments and situations in order to provide solutions that represent social values. Which means that, in fact, it is not the structures themselves that carry values, but designers who determine their values, depending on their needs.

When a need arises, we rarely anticipate it in advance; its nature becomes clear as soon as we are confronted with it. In other words, we must look inward to understand what we really want. This insight comes not from configuring various structural systems or listing objectives to try one after another, but again, through the lived experience of experiencing these factors. Our needs are revealed through the subtle gratification we feel when we are finally confronted with what we have been looking for. Moreover, people change their narrative about the values they carry, which makes possible a value system that is neither arbitrary nor predetermined. This portal of possibilities is made possible only through our emotions. It is only through them that the narrative of a building becomes a home, which is in fact the greatest potential that a structure can have.

7.2 Toward a New Tectonism

Powerful programs that have taken control of many parts of design have also influenced the tendency of people to engage less and less with the physical environment around them, following GPS for orientation instead of observing spaces, recording the most beautiful moments on their phone instead of experiencing them, relying on Instagram for their social interactions, or relying on Google and ChatGpt for the information we need to know about a certain place.

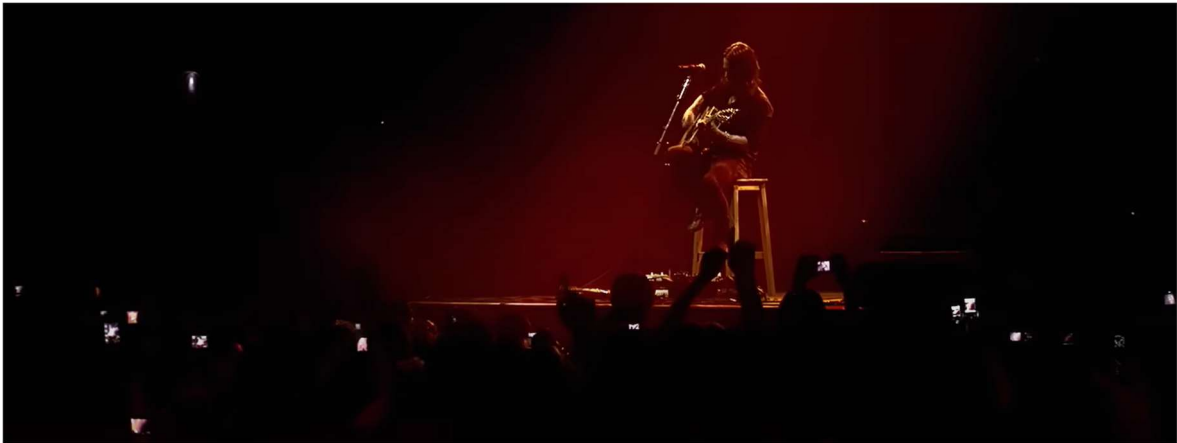


Figure 85 - Recording your moments during a live show

The result is a world conceived for a technological way of life that hinders our sensorimotor skills, a flattened world that has as part of it a growing sense of nihilism—a tendency to empty the world from values.

Based on the homogenization and globalization of society today, Daniel L. Smail alludes to the possibility that “[humans] will be tempted by the same package of sensory inputs and body stimulations, and that the capitalistic marketplace, evolving as it does towards optimal solutions, will eventually hit on the perfect package of psychotropic products and mechanisms.” [123] Although this is unlikely to happen due to the extremely high energy demand for the implementation of such projects, this dystopian future is also predicted by Francis Fukuyama, who states that it will be the end of history and will lead to “a radical ‘animalizing’ of human beings, and hardly a state of attunement.” [58] Only if this happens can the modern project and the digital project finally unleash their weapons and generate structures independent of humans.

What will happen if we accept that the discrete world is the same as full reality? I know that accurate predictions can never be made, but I can try, starting from the changes that are

taking place and the effects that these changes have brought to our fields. The definition of structural elements has not yet changed its ontology, but it may change it in the future. We have seen how this will bring great losses of structural design values, but we will never know the effect of the structures themselves that are designed in this spirit until (if) we find ourselves in that culture. For me, the future, whatever it may be, is optimistic. Even if we designers abandon the values of design and deal only with measurable computational objectives and abandon human methods of deciphering reality and accept discrete computer methods of representing reality, the structures that will be produced by this effect will not necessarily transmit the same effect. Despite all this, they will be alive, part of our full reality. Once the structures begin to rise and break free from the computer screen, they will transmit true values that will certainly be connected to the spirit of the time, but they will also release values independent of the designers and the computer capacity, as they have always done. How these two realities—the computer one, trusted by man, and the real one, liberated from structures—will collide, will provide messages for the cultural spirits beyond dystopian futures.

Since nature has already produced intelligent behavior, one solution may be for proper generative design to be able to elicit such behavior either by recreating nature as it is, or by growing programs in the same ways, conditions, and capacities that creatures grow in nature. It would be interesting if computer science moved towards this field and produced computers that are situated in the world, having a body like us and having the same cultural and social basis as us. This would mean that, instead of computers receiving data through digital exchanges, they would receive information directly from the full reality.

However, the computers we use have neither bodies nor senses, in the terms that I described in this thesis, and, since no one has any idea how to program the global organization and indeterminacy that characterize our embodied, perceptive sensory motor skills, the best we can hope for is a kind of first-person designing, which allows the structural designer to experience a part of reality firsthand inside the simulation.

Despite the computational dominant trend, which is driven by society's trust in the representation of reality through numerical data, the roots of this problem are deeper and cannot be addressed by digital design alone. Computer programs are not the cause of our cultural pathology. On the contrary, the task before us—if we want to design more valuable and healthier environments—is to engage with computer programs critically, taking into account the observations that have been raised in this thesis. This task will be for future

designers to pursue and explore further, but I can nevertheless give some advice now, with as many observations as I have made so far. For example, beyond the fact that we need to preserve a place untouched by the hegemony of the computer to allow for different ways of graphic expression through the body or senses—such as drawing by hand, physical modeling or working with building materials—another promising thing is to look for ways to exploit the linguistic imagination within digital programs themselves. In other words, we are faced with the question, “Is it possible to return to the experience of the world through mediations that reduce the wholeness of such experience to the binary code of ‘yes-es’ and ‘no-es’?” On this point, Vilayanur S. Ramachandran explains: “Your own body is a phantom, one that your brain has temporarily constructed purely for convenience.” [58] Which means that if we can explain why “[i]f your hidden hand and a rubber hand in front of it are stroked simultaneously while you concentrate on the rubber hand, you will feel the sensation on the rubber hand”, [58], then there may be reason to believe that our mood can be simulated. Pérez-Gómez shares the same belief when he says: “...it is possible to experience one’s sensations in another object.” [58]

For example, given the importance of the senses in experiencing situations, experiments could be conducted in which participants wear biometric sensors that record heart rate, skin conductance, or eye tracking while moving through virtual models. In this way, designers can visualize embodied affective responses such as how light, texture or spatial proportions affect the lived experience. Interpreting these findings of virtual reality in graphic representation tools is certainly not easy since we must always take into account the situational factor, which establishes its hegemony and makes the case unreproducible. The beauty of this method is that, instead of the designer holding a position as a “third party”, between the environment and the structure, he can experience a reality—however distorted it may be—by taking on the role of the first person directly experiencing the structure and the environment through the senses. In construction, this approach has not yet been explored, but video game software has made considerable progress in exploring the first-person position behind the screen, as well as efforts to bypass the screen through immersive 3D environments. In these cases, the problem of course remains the fact that reality can never be fully represented in simulation, but as long as we are aware of this, nothing stops us from doing such experiments. The first-person interaction with the virtual world should be like in everyday life. It should be dynamic, feeling your body moving through the room and interacting with the space through the movements of the air on your skin, the smell of pasta in the kitchen, or the soft touch of the parquet on your feet. This has been made possible in

so-called 5D projects, but only through additional mechanisms since it is still impossible to imagine something like this in a completely virtual model.

Other cases that follow the direction of using technology to create an embodied experience are, for example, software that have questioned the Cartesian system where the camera can simulate our vision so the designer/inhabitant can move around the building model. Regarding structural design, recent software allows one to work in non-Cartesian space and draw without having to deploy precise measurements, facilitating drawing as a thinking process. Such is the case with Minecraft, a videogame that inspired many youngsters to pursue an architecture or structural design degree, because of its purely experiential approach. However, making a structure in Minecraft is in stark contrast to a proper structural design, mainly for disregarding technical aspects and abstracting construction to make the experience less demanding. Yet, its spatial experience as a first-person crafter is so important that it has inspired an entire generation.

There may be another way to make structural design more open and inclusive. This can be achieved again through computers, which, by allowing participation and simplifying technicalities in a dynamic way, can allow the individuals involved to change the project according to their wishes. This idea is borrowed from Bill Mitchell, who claimed that urban projects, through the use of computers, could strengthen the participation of interest groups in urban design. [89] These groups would eventually have the opportunity to manipulate and control models of the environment. This is difficult for structural projects, given the high computational demands of structures, but not impossible.

According to Pérez-Gómez, fully simulating the spontaneity of embodied perception in time and space—particularly the experience of depth—is likely impossible. Perception is not a passive optical act but an enacted response: stepping back from large objects to better apprehend those nearby, or being drawn to certain colors and repelled by others. Since colors constantly shift with ambient light, he adds, they exemplify the everyday, embodied quality of perception that digital environments struggle to replicate. [58]

Even Dreyfus's observation on this issue is not very optimistic: "...it looks likely that in the virtual world the mood of the background space cannot come to resemble the mood of a similar space in the real world and so give guidance to the architect." [107]

However, I would prefer further research in this direction, rather than promises of entirely generative AI projects.

References

- [1] J. Whitelaw, 'Profile: Chris Wise'. The Structural Engineer, 2016.
- [2] A. Charlesson and S. Pirie, "An Investigation of structural engineer-architect collaboration," *Sesoc Journal*, 2009.
- [3] E. P. J. J. & P. M. Torroja, Philosophy of structures, University of California Press, 1962.
- [4] W. Gropius, The new architecture and the Bauhaus, (P. Morton Shand, Trans.). MIT Press. (Original work published 1935), 1965.
- [5] H. Petroski, To Engineer is Human: The Role of Failure in Successful Design, New York: Vintage Books, 1992.
- [6] P. Debney, Computational Engineering, The Concrete Centre, 2020.
- [7] S. Anderson, C. Balmond, H. Isler and D. Billington, Seven structural engineers: The Felix Candela lectures. Museum of Modern Art., (Eds.), 2011.
- [8] J. Till, Architecture Depends, MIT Press, 2009.
- [9] W. E. Connolly, Politics and Ambiguity, Madison: University of Wisconsin.
- [10] N. Leach, Rethinking Architecture: A Reader in Cultural Theory, Routledge, 1996.
- [11] P. Schumacher, Tectonism: Architecture for the twenty-first century, Wiley, 2022.
- [12] E. Fichtl, "ericfichtl," [Online]. Available: <https://ericfichtl.org/gallery/structures>.
- [13] C. A. "COX Architecture," 2020. [Online]. Available: <https://bit.ly/3MQh38U>.
- [14] D. Romm. [Online]. Available: <https://www.are.na/block/7095954>.
- [15] Madrid Destino. [Online]. Available: <https://bit.ly/44HGm39>.
- [16] C. 9. [Online]. Available: <https://arquitecturaviva.com/works/media-tic-building>.
- [17] J. E. Gordon, Structures: Or why things don't fall down, Penguin, 1978.
- [18] P. Claisse, Civil engineering materials, Butterworth-Heinemann, 2016.
- [19] C. Balmond, Informal, Prestel, 2002.
- [20] A. Charleson, Seismic design for architects, Elsevier, 2008.
- [21] Eurocode 8: Design of structures for earthquake resistance, EN 1998, 2004.
- [22] A. Konstantinidis, Earthquake resistant buildings, CRC Press, 2015.
- [23] G. Herbert, The dream of the factory-made house, MIT Press., 1984.
- [24] J. Pallasmaa, The eyes of the skin: Architecture and the senses, Wiley, 2005.
- [25] R. K. Maison à Bordeaux (1994–1998), "Architecture-History.org.," 2025. [Online]. Available: <https://shorturl.at/Ju5Zf>.
- [26] N. Yoshida, "Cecil Balmond". *Architecture and urbanism Chinese Edition*.
- [27] C. Balmond, Number 9 : the search for the sigma code : nine fixed points in the wind, Prestel, 1998.
- [28] C. Balmond, "balmondstudio.com," [Online]. Available: <https://shorturl.at/k2cCL>
- [29] O. Holmes, The one hoss shay, 1891.
- [30] K. Frampton, Studies in tectonic culture: The poetics of construction in nineteenth and twentieth century architecture, (J. Cava, Ed.). MIT Press, 1995.
- [31] C. Rowe, The Mathematics of the Ideal Villa and Other Essays, MIT Press, 1982.
- [32] L. Corbusier, Precisions.
- [33] Z. Bauman, Wasted Lives: Modernity and Its Outcasts, Cambridge: Polity Press, 2004.
- [34] Giddens, The Consequences of Modernity.
- [35] P. Eisenman, Eisenman Inside Out: Selected Writings 1963-1988, New Haven: Yale University Press, 2004.

- [36] G. Canguilhem, *A vital rationalist: Selected writings from Georges Canguilhem*, (F. J. Delaporte, Ed.). Zone Books., 1994.
- [37] Z. Bauman, *Intimations of Postmodernity*.
- [38] G. Di Giovanni, *The Category of Contingency in Hegelian Logic*, 1980.
- [39] Z. Bauman, *Modernity and Ambivalence*.
- [40] J. R. A Universal History of Contingency: Deleuze and Guattari on the History of Capitalism, *Bordelands*, 2003.
- [41] A. Melucci, *The Playing Self: Person and Meaning in the Planetary Society*, Cambridge: Cambridge University Press, 1996.
- [42] D. Haraway, "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective" in Haraway, Siminians, *Cyborgs and Women*, London: Free Association Books, 1991.
- [43] Dewey, *The Quest of Certainty*.
- [44] H. Lefebvre, *The Production of Space* trans. Donald Nicholson-Smith, Oxford: Blackwell, 1991.
- [45] S. Groák, *The Idea of Building: Thought and Action in the Design and Production of Buildings*, London: E. & F. N. Spon, 1992.
- [46] H. Lefebvre, *The Everyday and Everydayness*, Yale French Studies, 1987.
- [47] H. Lefebvre, *Everyday Life in the Modern World*.
- [48] M. Mostafavi and D. Leatherbarrow, *On Weathering*, 1993.
- [49] L. Lerup, *Building the Unfinished: Architecture and Human Action*, Beverly Hills: Sage, 1977.
- [50] H. Lefebvre, *Critique of Everyday Life*, trans. John Moore, London: Verso, 1991.
- [51] J. Shotter, *Cultural Politics of Everyday Life: Social Constructionism, Rhetoric and Knowing of the Third Kind*, Buckingham: Open University Press, 1993.
- [52] H. Sanoff, *Community Participation Methods in Design and Planning*, 2000.
- [53] R. Venturi, *Complexity and contradiction in architecture*, Museum of Modern Art, 1966.
- [54] R. B. & A. E. J. Fuller, *Synergetics: Explorations in the geometry of thinking*, Macmillan, 1975.
- [55] C. Jones, *Design Methods*, 2nd edn., New York: Van Nostrand Reinhold, 1992.
- [56] C. Price, *Cedric Price: Works II*, London: Architectural Association., 1984.
- [57] J. Forester, "Designing: Making Sense Together in Practical Conversations," *Journal of Architectural Education* 38, no.3, 1985.
- [58] A. Pérez-Gómez, *Attunement: Architectural meaning after the crisis of modern science*, MIT Press, 2016.
- [59] S. Giedion, *Space, time and architecture: The growth of a new tradition*, (5th ed.). Harvard University Press, 1976.
- [60] B. Munari, *Design as Art*, Penguin Modern Classics, 1966.
- [61] L. C. *Towards an architecture*, (J. Goodman, Trans.). Getty Research Institute. (Original work published 1923)., 2007.
- [62] P. Eisenman, *Aspects of modernism: Maison Dom-ino and the self-referential sign*, In *Oppositions* (Vol. 15–16, pp. 118–128). MIT Press., 1984.
- [63] J. Otero-Pailos, *Architecture's historical turn: Phenomenology and the rise of the postmodern*, University of Minnesota Press, 2010.
- [64] W. Gropius, *Apollo in the Democracy: The Cultural Obligation of the Architect*, New York: McGraw-Hill, 1968.

- [65] R. Banham, "A Black Box: The Secret Profession of Architecture", in Banham, A critic Writes, ed. Mary Banham, Berkeley: University of California Press, 1996.
- [66] C. Brooks, *The Well Wrought Urn*, Harcourt, Brace and World, New York, 1947.
- [67] F. Kiesler, *Pseudo-Functionalism in Modern Architecture* ed. Yehuda Safran, London: Architectural Association, 1989.
- [68] R. Vischer, *Über das optische Formgefühl*.
- [69] E. N. Rogers, *The Phenomenology of European Architecture*, 1964.
- [70] C. Norberg-Schulz, *Genius loci : towards a phenomenology of architecture*, 1979.
- [71] K. Frampton, *Rappel à l'ordre: The case for the tectonic.*, *Architectural Design*, 51(3/4), 19–25., 1981.
- [72] P. Collins, *Perret, Auguste*, New York: Free Press, 1982.
- [73] L. Kahn, *Form and Design*, 1961.
- [74] A. Konstantinidis, *Architecture*, 1964.
- [75] P. L. Nervi, *Nervi: Space and Structural Integrity*. Exhibition catalog, San Francisco: San Francisco Museum of Art, 1961.
- [76] A. Vernooy, *Crisis of Figuration in Contemporary Architecture*, New York: Rizzoli, 1992.
- [77] D. C. Llach, *Builders of the Vision: Software and Imagination of Design*, New York and London: Routledge, 2015, 2015.
- [78] M. McCullough, *Abstracting Craft: The Practiced Digital Hand*, The MIT Press. Cambridge, Massachusetts. London, 1996.
- [79] A. Tedeschi, *AAD – Algorithms-aided design: Parametric strategies using Grasshopper*, Le Penseur, 2014.
- [80] G. Deleuze, *Difference and repetition*, (P. Patton, Trans.). Columbia University Press. (Original work published 1968), 1994.
- [81] Le Corbusier, *The Decorative Art of Today*, London: Architectural Press, 1987.
- [82] J. Stirling, *James Stirling: Buildings and Projects 1950-1974*, London: Thames and Hudson, 1975.
- [83] Z. Bauman, *Alone Again: Ethics after Certainty*, London: Demos, 2000.
- [84] C. Levi-Strauss, *Tristes Tropiques*, New York: Atheneum, 1981.
- [85] RIBA Catalogue, *The Work of Peter Rice*, London: RIBA Publications, 1992.
- [86] M. Heidegger, *Being and Time*, transl., SCM Press, 1962.
- [87] K. Karatani, *Architecture as Metaphor*.
- [88] R. Piano, *Renzo Piano Building Workshop 1964-1991: In Search of a Balance*, Tokyo: Process: Architecture 100, 1992.
- [89] P. Jones, D. Petrescu and J. Till, *Architecture and Participation*, Spon Press, 2005.
- [90] B. Colomina, "Mies Not," in *The Presence of Mies*, ed. Detlef Mertins, New York: Princeton Architectural Press, 1994.
- [91] L. C. When the Cathedrals Were White: A Journey to the Country of Timid People, trans. Francis Hyslop, London: Routledge, 1947.
- [92] B. S. Herrnstein, *Contingencies of Value*, 1988.
- [93] B. Latour, *We Have Never Been Modern*, trans. Catherine Porter, New York: Harvester Wheatsheaf, 1993.
- [94] S. Kwinter, *Architectures of Time*.
- [95] B. A. [Online]. Available: <https://www.bofill.com/projects/barcelona-tower/>.
- [96] M. S. Roudsari, "[Post]. LinkedIn. linkedin.com," 2025. [Online]. Available: <https://bit.ly/4jgrUVK>.

- [97] NorwayChess, Magnus Carlsen is the Champion of Norway Chess 2025! YouTube, c. June 2025. [Online], <https://www.youtube.com/watch?v=9vVOS-jNfog&t=1s>
- [98] A. Sweigart, Automate the boring stuff with Python, (2nd ed.). No Starch Press, 2020.
- [99] M. Betancourt, "Automated Labor: The 'New Aesthetic' And Immaterial Physicality," *CTHEORY*.
- [100] W. Benjamin, The work of art in the age of mechanical reproduction, Penguin. (Original work published 1935), 2008.
- [101] S. Turkle, Simulation and its discontents, MIT Press, 2009.
- [102] D. Whitman, "Workshop on simulation and visualization in the professions, MIT, may 2005".
- [103] M. Merleau- Ponty, Phenomenology of Perception, Routledge & Kegan Paul, 1962.
- [104] G. Downey, The Machine in Me: An Anthropologist Sits among Computer Engineers, New York: Routledge, 1998.
- [105] M. Foucault, Discipline and Punish: The Birth of the Prison, Pantheon Books, 1978.
- [106] F. Selmani, "[Post]. LinkedIn. linkedin.com," 2025. [Online]. Available: <https://bit.ly/4qoknqf>.
- [107] H. L. Dreyfus, What computers still can't do: A critique of artificial reason, MIT Press, 1992.
- [108] M. Johnson, The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason, 1987: Chicago: The University of Chicago Press.
- [109] G. Miller, E. Galanter, K. H and Pribram, Plans and Structure of Behavior, New York: Holt, Rinehart and Winston, 1960.
- [110] A. Gurwitsch, "'On the Conceptual Consciousness," in The Modeling of Mind".
- [111] A. Newell and S. H., Computer Simulation of Human Thinking, The RAND Corporation, 1961.
- [112] G. Hinton, "Retrieved from <https://www.youtube.com/@NobelPrize>," 2025. [Online]. Available: <https://bit.ly/3YFSnT8>.
- [113] J. von Neumann, Probabilistic Logics and the Synthesis of Reliable Organisms from Unreliable Components, Collected Works, A.H. Taub, ed., New York: Pergamon Press, 1963.
- [114] J. von Neumann, The General and Logical Theory of Automata, reprinted in The World of Mathematics, New York: Simon and Schuster, 1956.
- [115] W. Rosenblith, On Cybernetics and the Human Brain, The American Scholar, 1966.
- [116] H. Simon and N. A., Information Processing in Computer and Man, American Scientist, 1964.
- [117] H.-J. Bremermann, Optimization Through Evolution and Recombination in Self-Organizing Systems, Washington, D.C., 1962.
- [118] M. Minsky, Semantic Information Processing, 1968.
- [119] J. Maciejewska, 29 March 2024. [Online]. Available: <https://x.com/AuthorJMac/status/1773679197631701238?lang=en>.
- [120] G. Kasparov, The Chess Master and the Computer, The New York Review of Books, 2010.
- [121] M. Merleau-Ponty, Signs, Evanston, III, 1960.
- [122] O. Paz, The Bow and the Lyre.
- [123] D. Smail, On Deep History and the Brain, Berkeley: University of California Press.
- [124] N. Crossley, The Social Body, London: Sage, 2001.
- [125] G. Lakoff and M. Johnson, Metaphors We Live By, 1980.

- [126] W. Rosenblith, *Computers and the World of the Future*, Martin Greenberger, ed., Cambridge, Mass.: MIT Press, 1962.
- [127] E. Feigenbaum, *Artificial Intelligence: Themes in the Second Decade*, IFIP Congress '68, Final Supplement, 1968.
- [128] B. R. Sevaldson, *Developing digital design techniques*, 2005.
- [129] A. Sorokovikova, A. Chizhov, V. Eremenko and I. P. Yamshchikov, *Surface fairness, deep bias: A comparative study of bias in language models*, arXiv. <https://arxiv.org/abs/2506.10491>, 2025.
- [130] N. Chomsky, *Language and mind*, 2nd ed., 1972.
- [131] H. Simon, *The Shape of Automation for Men and Management*, New York: Harper & Row, 1965.
- [132] U. Neisser, *Cognitive Psychology*, New York: Appleton-Century-Crofts, 1967.
- [133] L. Wittgenstein, *Zettel*, Berkeley: University of California Press, 1967.
- [134] R. Solnit, *A Field Guide to Getting Lost*, Edinburgh: Canongate Books, 2006.
- [135] S. Watanabe, *La Simulation mutuelle de l'homme et la machine*, transl. Hubert Dreyfus, Lausanne, 1965.
- [136] H. Gadamer, *The Relevance of the Beautiful and Other Essays*, trans. Nicholas Walker (Cambridge: Cambridge University Press, 1986).
- [137] L. Carroll, *Sylvie and Bruno Concluded*, New York: MacMillan Publishers, 1893.
- [138] J. Hegarty, *Hegarty on Creativity: There are No Rules*, 2014.
- [139] P. Eisenman, *Diagram Diaries*, 1999.
- [140] J. Carlson, "gothamist.com," 8 March 2012. [Online]. Available: <https://shorturl.at/WItMJ>.
- [141] Z. Bauman, *Postmodern Ethics*, Oxford: Blackwell, 1993.
- [142] H. Jonas, *The Imperative of Responsibility: In Search of an Ethics for the Technological Age*, Chicago: University of Chicago Press, 1984.
- [143] T. Charles, *Human Agency and Language*, Cambridge: Cambridge University, 1985.
- [144] J. Barry, *Report on the Battle between Good and Bad Modern*, 1953.
- [145] R. o. A. VENDIM Nr. 457, datë 29.6.2022 PËR DISA SHITESA DHE NDRYSHIME NË VENDIMIN NR. 408, DATË 13.5.2015, TË KËSHILLIT TË MINISTRAVE, "PËR MIRATIMIN E RREGULLORES SË ZHVILLIMIT TË TERRITORIT", TË NDRYSHUAR.
- [146] C. Voss, *Never Split the Difference: Negotiating As If Your Life Depended On It*, 2016.
- [147] N. Taleb, *The Black Swan: The Impact of the Highly Improbable*, 2007.
- [148] Eurocode 2: *Design of concrete structures – Part 1-1: General rules and rules for buildings*, EN 1992-1-1, 2004.
- [149] D. Lenat, *Computer Software for Intelligent Systems*, Scientific American, 1984.

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Appendix

This part investigates the method of algorithmic design as a way to facilitate the process of structural design. Algorithmic design enables the creation of objects and detailed structural elements by allowing users to define a set of variable parameters. Through interactions between these parameters, structural designers can easily modify dimensions, quantities, and other factors, leading to automatic generative design.

The scripts are made from the author, using Grasshopper. The purpose of the scripts is to program the logic behind the design of reinforced concrete structures, according to Eurocode 2 [148], as well as to help structural designers in the decision-making process. The user can have the desired projects by changing the values of the inputs, which are selected, keeping in mind the flexibility during work. The number of inputs are intended to be as minimal as possible to facilitate the drafting process as much as possible.

Beam and column typologies

The main problem, rather than creating the flow of the algorithm, was to decide the inputs. Since the drafting process has so many inputs, the author had to determine which input should the algorithm consider; Will it consider the material properties? What if it includes the bending moment? Should the script consider other inputs that are not destined to be chosen from the design codes, like the maximal length of the rebars?

Programmers deal with similar problems all the time. The best solution to it usually is “What the client wants.” In this case, the author is the client, which is the best case, as the author is a structural designer and the input were chosen based on professional experience.

Table 3 - The inputs for reinforced concrete beams

Bake	1	Cover	24
Number of beams	2	Upper rebars diameter	25
Axis name in the cross-section	3	Lower rebars diameter	26
Lower quote	4	Upper rebars number	27
Thickness	5	Lower rebars number	28
Length	6	Is there another element attached to the left?	29
Axes names in the longitudinal section	7	Left element thickness	30
Number of axes	8	Left element length	31
Axis 1 to 25 - length	9	Is there another element attached to the right?	32
Number of cross elements that intersect the beam	10	Right element thickness	33
Cross element 1 to 19 - intersection length	11	Right element length	34
Number of lower columns	12	Stirrups diameter	35
Lower columns 1 to 19 - intersection length	13	Stirrups step on the critical path	36
Is there a column above column 1...19?	14	Stirrups step on the non-critical path	37
Number of upper columns	15	Maximal allowed rebar length	38
Upper columns 1 to 19 - intersection length	16	Cross section scale	39
Dimension of the axis from the left side of the cross section	17	Are there any additional rebars on the upper level?	40
Width	18	Are there additional rebars at the column 1...19?	41
Stirrup fold length	19	Additional rebar 1 to 19 number	42
Fixing rebars diameter	20	Additional rebar 1 to 19 diameter	43
Supplementary rebars diameter	21	Ancorage tolerance	44
Staples form	22	Axis tolerance	45
Staples diameter	23		

The algorithm is destined to be controlled by a structural designer. Hence, it does not have inputs for automatically calculating the rebar dimensions or the concrete cover. This input values should be added manually into the script. This is because there are too many reasons why the size of the rebars chosen do not necessarily respect the design codes formulas, in practice. One reason can be the requirements from the public administration, or it can be the over-standardization of the elements to save time and money, or even the good practice of structural designers, guided by their experience.

Another input is the length of the maximal rebars, which is often neglected when designing software. The typical limit is 12 meters. However, this length is sometimes not preferable, as the rebars tends to buckle during their transportation in site or during their implementation. Therefore, the author made an input for the user to consider the maximal length of the rebars.

A lot of inputs are made for the geometry of the beam which, again, has to be putted manually by the engineer. BIM software deal with this issue differently, by having inputs for 3D objects and, afterwards generating the 2D drafting automatically. This is not preferable, not only in the Albanian community of structural designers, but in many other countries in Europe, as the structural designers have not yet overcome the transition from the 2D page to the 3D workspace and the chances are that this gap will not be overtaken in the recent future. To help them, the script is designed with inputs in 2D, similarly as if the drafting would be made in a worksheet plan in Autocad. The difference here is that, while the drawing is time consuming, not changeable and includes human mistakes, drafting using “buttons” from the script resolves these issues. It saves precious time!

Another important input is the scale button, which allows the user to change the scale of the cross section, without changing the size of the text or symbols. The current programs need additional steps to make the dimensions and symbols immutable, while growing or lowering the size of the geometry. This script surpasses this limit. Moreover, the script produces the concrete and rebar quantity table, which is needed for cost estimation.

The last input is the “Bake” button. This tool allows the user to decide whether or not to let the program draw the beam. After the Bake process, the beam is not changeable by the scripts, but the lines itself can be modified manually, as if they were drawn in Autocad.

Because of the large number of the inputs, the flow takes its time to amalgamate into a single output. The main issues here were to keep track and to manage all the possible connections between the inputs. Therefore, the author uses panels for the unwanted inputs and number sliders for the important ones. Another solution to this problem is the use of groups, clusters and scribbles inside the script.

Again, some of the possible inputs were deleted, because of the engineer’s judgment. For example, considering the minimal distance between the rebars in the cross section, the script has a conditional clause that set the bars in one layer or in two or more layers automatically. Similarly, the algorithm considers not having rebar joints in short beams. Moreover, the script makes all the rebar lengths rounded by numbers fully distributed by 5, by not changing the joint length between them. In this case, the center of the joints is not on the axis for the lower bars and not on the exact middle of the span for the upper bars. Instead, these points move a little.

Furthermore, when considering the additional upper bars, their lengths is set automatically, based on the Eurocode 2. [148] They are rounded by numbers fully distributed by 5, as well. This round is important because rebars are usually cut on site. If bars have miscellaneous lengths, it results in a lot of wasted material.

Another automatic draw which the script realizes (though we are just scratching the surface here, as the script includes an enormous range of flows, regarding the engineer requirements), is the middle bars into the section beam, which are made with a conditioning clause, depending on the height of the beam. If the beam is deep enough, it will suffer from the out-of-plane moment and the stirrups will suffer from buckling. To prevent possible local failures in these particular cases, the script considers the drawing of middle bars. Also, the algorithm is designed to let the user decide if he want to draw ties. If he decide so, the algorithm automatically connects at least one bar out of two of them in a row.

The most important advantage of the script is his flexible nature. Let’s imagine a normal day of work in a design office. The drawings are made for the team leader. After his corrections, they are re-done, this time hoping that the client wont make changes. Usually, this is not the

case, as clients tend to have mixed feelings and they can be the reason for the project to change through all the steps of its design. However, the municipality tends to change the projects, as well. The projects can also change in site. Usually in Albania all of the above happen. The project may change even when the building is finished. Sometimes not only some elements, but the entire project changes.

To prevent the possible mental breakdown during these changes, the script allows the user to be flexible and change only the corresponding inputs, not the entire project. The drawings, afterwards, adapt to the changes in an automatic way, by saving a lot of time.

Lastly, the script prevents human mistakes. The test was made during a workshop in Tirana Architecture Weeks 2023. A simpler version of the script was given to the students of the first year of civil engineering class and they were assigned to draw all the cross sections of beams and columns of a five-floor complex structure. Students lacked the skills to do this task with a conventional software. Moreover, they did not have the capabilities to understand the meaning behind the drawings. Nevertheless, the result was outstanding. It took only one day to explain the problem to them. They completed the drawings in four days. Also, the drawings themselves had less mistakes than the real drawings, which were done by experienced engineers.

Table 4 - The parameters used to generate columns drawings with scripts, during the design of Building 2

Parameters	
Bake me!	TRUE
How many columns are like this in the same structure?	4
Cross section scale	1:20
Dimension of the vertical axis from the left side of the cross section (cm)	15
Dimension of the horizontal axis from the upper side of the cross section (cm)	15
Vertical axis name	A
Horizontal axis name	1
Rebar numbers at x direction	4
Rebar numbers at y direction	4
Cover (cm)	2.5
Length (cm)	30
Width (cm)	30
Rebar overlapping length (cm)	100
Number of stories	2
Story 1 (cm)	306
Story 2 (cm)	306
Stirrups critical path step (cm)	10
Critical path length (cm)	110
Stirrups non-critical path step (cm)	15
Dimension of the first stirrup from the column (cm)	1
Footing thickness (cm)	40
Beam thickness at story 1 from the left of the column (cm)	50
Beam thickness at story 1 from the right of the column (cm)	50
Beam thickness at story 2 from the left of the column (cm)	50
Beam thickness at story 2 from the right of the column (cm)	50
Longitudinal rebar diameter (mm)	16
Stirrups diameter (mm)	10
Footing cover (cm)	4.5
Ground floor elevation (m)	-0.10

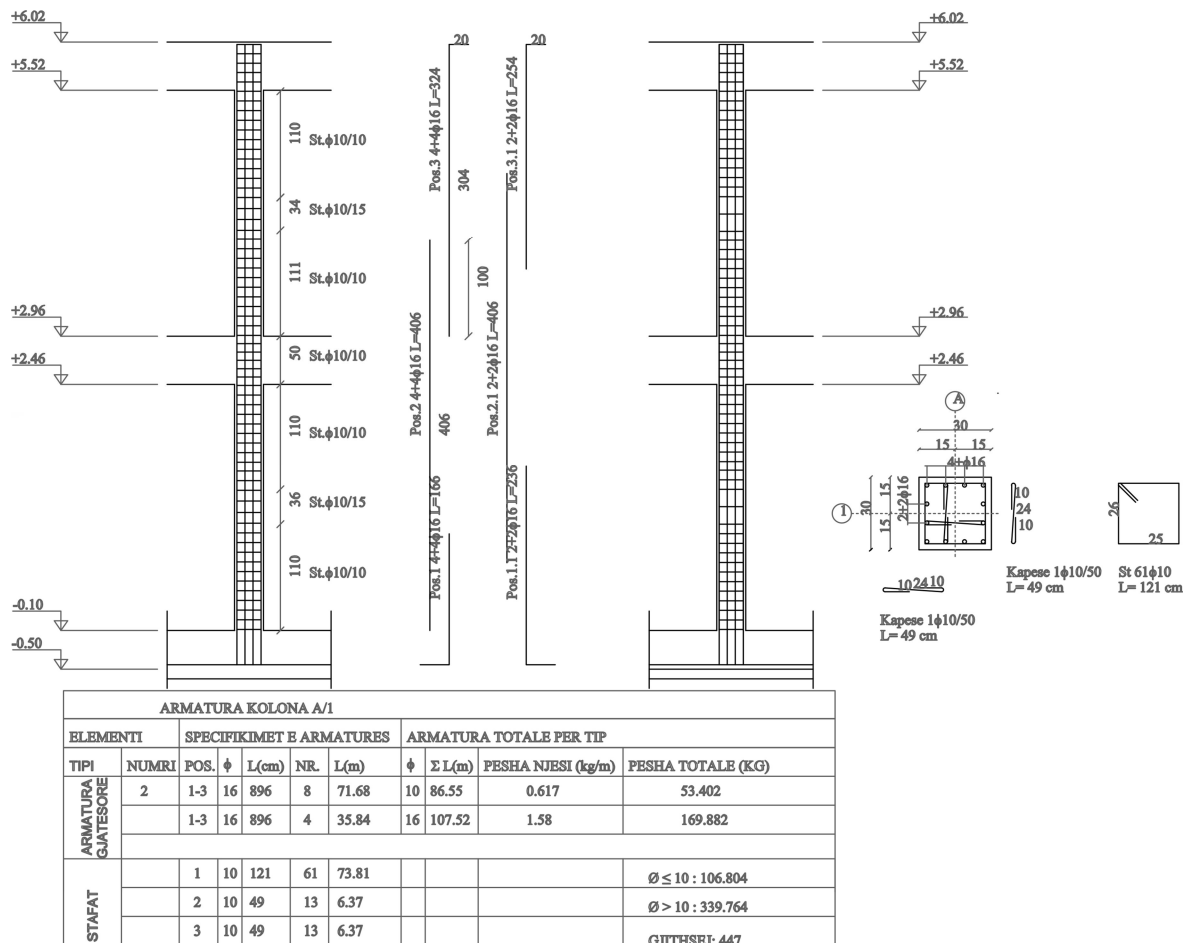


Figure 86 - An output sample of the algorithm for columns

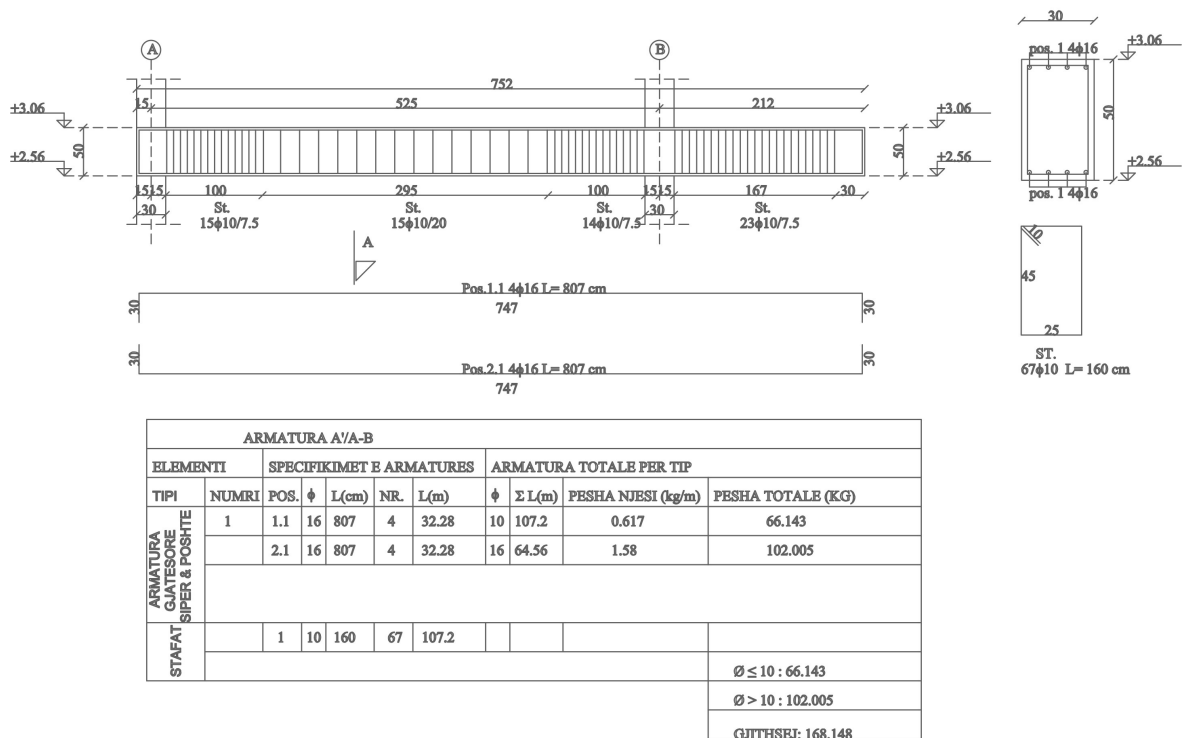


Figure 87 - An output sample of the algorithm for beams

Slab Typologies

The algorithm that designs reinforced concrete slabs starts by considering the number of axis in the direction x and y, with the assumption that the distance between axes of the same direction gives the respective spans of a structure. The structure footprint does not have to be completely overwrite into axes, as the maximal and minimal span on each direction is enough to decide on element typologies. Hence, the first inputs decided for the script were the number of axes and the respective spans in both directions, creating a grid into the interface of the software. In order to check for possible bugs, when using the script, another set of tools is applied to make the input of axes length dependent on the number of axes. Other inputs that were included were the calculation of loads, considering the function of the structure and function of the floor usage, together with the cost/unit of the rebar and slab typologies.

These inputs are mixed into the algorithm to select the typology of slabs from the four types mentioned below:

1. The one-way solid slab;
2. The two-way solid slab;
3. The one-way ribbed slab;
4. The waffle slab.

First, the algorithm calculates the rebar quantity and the minimal thickness regarding the strength and stiffness constraints. Then, it takes into account the cost of each typologies.

Lastly, all the values of material costs are combined in a list and are sorted, getting the lowest value. Regarding the lowest value, the algorithm searches into its parts the corresponding typology of the slab and the respective depth and the reinforcement quantity, and gives the final answer.

These values are returned from a panel in a final output, which shows the cheapest typology, the direction of the ribs (in case the typology is a ribbed slab), the rebar quantity and the rebar diameters, and the stirrups quantity and diameters (if the typology is a ribbed or a waffle slab). Lastly, the script return the thickness value of the slab and the overall construction cost.

An example using scripts to design the first-floor slab for Building 2:

Table 5 - Slab parameters of the second building

Parameters			
spans (mm)	Mini-slab 1	x	1550
		y	5820
	Mini-slab 2	x	5820
		y	5820
Cost of rebar quantity Ø 6 - 10 mm (lek/ton)			127636.5
Cost of rebar quantity Ø > 12 mm (lek/ton)			123074.87
	Concrete compressive strength (MPa)		25
Ribbed slab geometry	Rib width (cm)		12
	Flange thickness (cm)		5
	Ribbed slab thickness		30
	Solid slab thickness (cm)		16
	Live load (kn/m)		2
	Cover (mm)		25
	Steel tensile strength (MPa)		500
	Rebar lap in solid slabs		20
	Mounting rebar diameter (mm)		8
	Stirrups diameter (mm)		8
	Layer 1 thickness (m)		0.02
	Layer 1 density (kg/m3)		2000
	Layer 2 thickness (m)		0.02
	Layer 2 density (kg/m3)		2000
	Layer 3 thickness (m)		0.02
	Layer 3 density (kg/m3)		2000
	Layer 4 thickness (m)		0.02
	Layer 4 density (kg/m3)		2000
	Layer 5 thickness (m)		0.02
	Layer 5 density (kg/m3)		2000
	Bricks density for ribbed slabs (kg/m3)		800

The output:

“Choose a one-way rib slab, with ribs in direction x;

$h = 30$ cm;

Rebar quantity:

2 ϕ 10 in the upper area, 2 ϕ 12 in the lower area.

Stirrups ϕ 8/20, mounting rebars ϕ 8/25/50.

$t = 30$ cm.

Cost: 238882 lek”